



# Breeding Bird Monitoring Protocol for the Mid-Atlantic Network

Natural Resource Report NPS/MIDN/NRR—2018/1769



**ON THE COVER**

Scarlet tanager (*Piranga olivacea*)

Photograph by Bill Tucker

---

# **Breeding Bird Monitoring Protocol for the Mid-Atlantic Network**

Natural Resource Report NPS/MIDN/NRR—2018/1769

Mark J. Johnson<sup>1</sup> and Sarah M. Wakamiya<sup>2</sup>

<sup>1</sup>National Park Service  
Mid-Atlantic Inventory and Monitoring Network  
120 Chatham Ln  
Fredericksburg, VA, 22405

<sup>2</sup>National Park Service  
San Francisco Bay Area Inventory and Monitoring Network  
Fort Cronkhite, Bldg. 1063  
Sausalito, CA 94965

September 2018

U.S. Department of the Interior  
National Park Service  
Natural Resource Stewardship and Science  
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from [Mid-Atlantic Inventory and Monitoring Network Website](#) and the [Natural Resource Publications Management website](#). If you have difficulty accessing information in this publication, particularly if using assistive technology, please email [irma@nps.gov](mailto:irma@nps.gov).

Please cite this publication as:

Johnson, M. J., and S. M. Wakamiya. 2018. Breeding bird monitoring protocol for the Mid-Atlantic Network. Natural Resource Report NPS/MIDN/NRR—2018/1769. National Park Service, Fort Collins, Colorado.

# Contents

|                                                             | Page |
|-------------------------------------------------------------|------|
| Figures.....                                                | v    |
| Tables.....                                                 | vi   |
| Appendices.....                                             | vi   |
| Revision History .....                                      | vii  |
| Executive Summary .....                                     | viii |
| Acknowledgments.....                                        | ix   |
| List of Acronyms .....                                      | x    |
| 1. Background and Objectives .....                          | 11   |
| 1.1 Background and History.....                             | 11   |
| 1.2 Landscape setting .....                                 | 12   |
| 1.3 Rationale for Monitoring Breeding Birds.....            | 13   |
| 1.4 History of Breeding Bird Monitoring in MIDN Parks ..... | 14   |
| 1.5 Protocol Objectives .....                               | 15   |
| 2. Sampling Design.....                                     | 16   |
| 2.1 Sampling Design Rationale .....                         | 16   |
| 2.2 Target population.....                                  | 17   |
| 2.3 Site Selection.....                                     | 18   |
| 2.4 Sampling Frequency and Replication.....                 | 20   |
| 2.5 Power Analysis.....                                     | 21   |
| 3. Field Methods .....                                      | 23   |
| 3.1 Field Preparations and Scheduling .....                 | 23   |
| 3.2 Field Sampling Methods.....                             | 24   |
| 3.3 Post-Collection Processing.....                         | 24   |
| 4. Data Management .....                                    | 25   |
| 4.1 Overview of Database Design.....                        | 25   |
| 4.2 Data Transcription, Entry, and Validation.....          | 25   |
| 4.3 Data Certification and Archiving .....                  | 25   |
| 5. Data Analysis and Reporting .....                        | 27   |

## Contents (continued)

|                                                  | Page |
|--------------------------------------------------|------|
| 5.1 Annual Data Summaries.....                   | 27   |
| 5.2 Multi-year Synthesis Reports .....           | 27   |
| 6. Personnel Requirements and Training .....     | 29   |
| 6.1 Roles and Responsibilities.....              | 29   |
| 6.2 Field staff and Volunteer Requirements ..... | 29   |
| 6.3 Training .....                               | 30   |
| 6.4 Safety .....                                 | 30   |
| 7. Operational Requirements .....                | 31   |
| 7.1 Annual Workload and Field Schedule.....      | 31   |
| 7.2 Facility and Equipment Needed .....          | 31   |
| 7.3 Operational Costs .....                      | 31   |
| 7.4 Protocol Revision .....                      | 32   |
| 8. Literature Cited .....                        | 33   |

# Figures

|                                                                                                                                                                                                                      | Page |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| <b>Figure 1.</b> Map of Mid-Atlantic Network parks and associated Bird Conservation Regions. ....                                                                                                                    | 13   |
| <b>Figure A1.</b> Aerial image of Booker T. Washington National Monument (BOWA) showing active forest (green) and grassland (yellow) monitoring locations. ....                                                      | 39   |
| <b>Figure A2.</b> Aerial image of the Spotsylvania Battlefield Unit of Fredericksburg and Spotsylvania National Military Park (FRSP) showing active forest (green) and grassland (yellow) monitoring locations. .... | 40   |
| <b>Figure A3.</b> Aerial image of the Eastern Front unit of Petersburg National Battlefield (PETE) showing active forest (green) and grassland (yellow) monitoring locations. ....                                   | 41   |
| <b>Figure A4.</b> Aerial image of the Malvern Hill unit of Richmond National Battlefield Park (RICH) showing active forest (green) and grassland (yellow) monitoring locations. ....                                 | 42   |
| <b>Figure A5.</b> Aerial image of Valley Forge National Historical Park (VAFO) showing active forest (green) and grassland (yellow) monitoring locations. ....                                                       | 43   |

## Tables

|                                                                                                                                                                                                                            | Page |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| <b>Table 1.</b> List of Mid-Atlantic Network parks displaying their participation status in the Breeding Bird Monitoring Program and their associated sampling frames.....                                                 | 20   |
| <b>Table 2.</b> List of supplemental and Standard Operating Procedure documents for avian monitoring in the MIDN. ....                                                                                                     | 23   |
| <b>Table 3.</b> Roles and responsibilities for avian monitoring in the MIDN. ....                                                                                                                                          | 29   |
| <b>Table 4.</b> Yearly schedule of protocol activities for avian monitoring in the MIDN. ....                                                                                                                              | 31   |
| <b>Table 5.</b> Estimated annual operational costs associated with the implementation of the Mid-Atlantic Breeding Bird Monitoring Protocol based on 2018 salary and benefit costs.....                                    | 32   |
| <b>Table A1.</b> List of Mid-Atlantic Network parks currently participating in the Breeding Bird Monitoring Program and the number of sampling locations for each park. ....                                               | 38   |
| <b>Table B1.</b> Power estimates to detect a change in species point occupancy (10 or 50 percent declines) under 5-, 10-, 15-, and 20-year annual sampling frameworks for species observed within MIDN park units. ....    | 46   |
| <b>Table B2.</b> Power estimates to detect a change in species abundance (10 or 50 percent declines) under 5-, 10-, 15-, and 20-year annual sampling frameworks for species observed within MIDN park units. ....          | 48   |
| <b>Table B3.</b> Power estimates to detect a change in bird community index (BCI) trends (50 or 10 percent declines) under 5-, 10-, 15- and 20-year annual sampling frameworks of forested points in MIDN park units. .... | 49   |
| <b>Table C1.</b> List of 128 species with corresponding common names, Latin names, and 4-letter American Ornithological Union (AOU) codes detected at forest and grassland monitoring plots within MIDN park units. ....   | 51   |

## Appendices

|                                             | Page |
|---------------------------------------------|------|
| Appendix A. Maps of sampling locations..... | 38   |
| Appendix B. Power Analysis.....             | 44   |
| Appendix C. Species List.....               | 51   |

## Revision History

The MIDN breeding bird monitoring protocol consists of a narrative (this document), Standard Operating Procedures (SOPs) that outline specific aspects of the monitoring protocol, and a Quality Assurance Plan document that establishes standards for data quality.

The latest version of each and additional supporting information can be accessed online at the National Park Service's Mid-Atlantic Network website (<https://www.nps.gov/im/midn>) and at the Service's integrated resource management information portal (<https://irma.nps.gov/DataStore/Reference/Profile/2256611>).

The narrative, each SOP, and the Quality Assurance Plan document have revision history logs to document changes. The following revision history log is for the protocol narrative.

Version numbers will be incremented by a whole number (e.g., Version 1.0 to 2.0) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.3 to Version 1.4) when there are minor modifications. Rows are added to the log as needed for each change or set of changes tied to an updated version number.

| Prev.<br>Version # | Revision<br>Date | Author | Changes Made | Reason for Change | New<br>Version # |
|--------------------|------------------|--------|--------------|-------------------|------------------|
|                    |                  |        |              |                   |                  |
|                    |                  |        |              |                   |                  |
|                    |                  |        |              |                   |                  |
|                    |                  |        |              |                   |                  |
|                    |                  |        |              |                   |                  |

## Executive Summary

The Mid-Atlantic Network (MIDN) of the National Park Service's Inventory and Monitoring Division (IMD) was established to serve 10 national parks in Pennsylvania and Virginia spanning the Blue Ridge, Piedmont, and Coastal Plain of the Mid-Atlantic region. This protocol outlines the justification and procedures for establishment of a long-term breeding bird monitoring program for network parks. This protocol is administered by Mid-Atlantic Network staff in cooperation with the Natural Resource Management (NRM) staff of each participating park and utilizes citizen scientists to aid in data collection. In an effort to establish this monitoring program, a protocol has been developed and pilot tested in six participating network parks.

The primary objectives of this protocol are to determine the status and long-term trends in breeding bird species composition, relative abundance, and occupancy, and evaluate changes in bird populations relative to park management regimes. The sampling design was developed to address the priorities of each network park through consultation with park NRM staff and engagement with subject matter experts. The design should provide enough power to both address the status of breeding bird populations in network parks, as well as detect changes in trends in these data over time. Protocol procedures were developed to meet protocol objectives, address resource management needs, and provide opportunities for citizen scientists to contribute significantly to their local park and the MIDN network as a whole.

This protocol consists of a narrative (this document), Standard Operating Procedures (SOPs) outlining specific aspects of the monitoring protocol, and a Quality Assurance Plan document that establishes standards for data quality. Data collected as part of this protocol are stored locally in databases developed by the network and uploaded to the National Park Service's Data Store application, available via the Integrated Resource Management Application Portal (<https://irma.nps.gov/DataStore/>). Reporting on these data occurs at regular intervals to enable park NRM staff to incorporate results into park management. The latest versions of the SOPs, data summary reports, and additional supporting information can be accessed online at the National Park Service's Mid-Atlantic Network website (<https://www.nps.gov/im/midn>).

## Acknowledgments

Many individuals were involved in the development of this program. This protocol is heavily based on bird monitoring protocols developed by the Northeast Temperate Network (NETN)(Faccio et al. 2015), the National Capital Region Network (NCRN)(Dawson and Efford 2013), and Eastern Rivers and Mountains Network (ERMN)(Marshall et al. 2016), and has benefited greatly from those Networks' earlier work. Extensive thanks go to Nicholas Bircher for gathering resources, coordinating volunteers, and getting the program off the ground. We also thank Sara Goodwin and Greg Shriver for the early development of data analysis and reporting. Zachary Ladin provided assistance with power analysis and Johanna Fickenschner ran some preliminary analyses. Penelope Pooler provided advice on statistical analysis. We would also like to thank Jim Comiskey, Regional I&M Program Manager NER for his continued support for the implementation of all Mid-Atlantic Network inventory and monitoring activities. We are grateful to Rodney Siegel, Executive Director for the Institute for Bird Populations for his thoughtful and helpful comments on this manuscript. We also extend thanks to the resource managers, including Kristen Allen, Tim Blumenschine, Brian Eick, Kate Jensen, Gregg Kneipp, Amy Ruhe, and Timbo Sims, and many of their bio-technicians for their logistical support and feedback. A special thank you to Anne and Bill Tucker for their many years of volunteer effort and for providing such great photographs for our protocol documents. Last but not least, we are indebted to all the volunteers, whom, regretfully, are too numerous to name, for completing the sometimes challenging field work of counting birds.

## List of Acronyms

APCO: Appomattox Courthouse National Historical Park

BCR: Bird Conservation Region

BOWA: Booker T. Washington National Monument

EISE: Eisenhower National Historic Site

FRSP: Fredericksburg and Spotsylvania National Military Park

GETT: Gettysburg National Military Park

GPS: Global Positioning System

HOFU: Hopewell Furnace National Historic Site

I&M: Inventory and Monitoring Program

IRMA: Integrated Resource Management Applications

MIDN: Mid-Atlantic Network

NABCI: North American Bird Conservation Initiative

NCRN: National Capital Region Network

NETN: Northeast Temperate Network

NRM: Natural Resource Management

NRPP: Natural Resources Preservation Program

NPS: National Park Service

PETE: Petersburg National Battlefield

RICH: Richmond National Battlefield Park

SAC: Science Advisory Committee

SHEN: Shenandoah National Park

SOP: Standard Operating Procedure

USGS: United States Geological Survey

VAFO: Valley Forge National Historical Park

WASO: Washington-Area Service Office

# 1. Background and Objectives

This breeding bird monitoring protocol outlines our objectives and strategy for monitoring avian populations within the National Park Service (NPS) Mid-Atlantic Network (MIDN). This protocol is based on bird monitoring protocols developed by the Northeast Temperate Network (NETN) (Faccio et al. 2015), the National Capital Region Network (NCRN) (Dawson and Efford 2013), and the Eastern Rivers and Mountains Network (ERMN) (Marshall et al. 2016) to bridge ecosystem similarities and to maximize compatibility of data for regional analyses.

The development of a long-term monitoring program requires thorough planning to ensure that monitoring will meet the critical information needs of each park, and produce scientifically credible data that are accessible to park Natural Resource staff in a timely manner. With these goals in mind, each network follows an explicit process for development and implementation (Fancy et al. 2009), including the creation of a peer reviewed network monitoring plan (Comiskey and Callahan 2008) and a series of detailed, peer reviewed, monitoring protocols that describe how data are to be collected, managed, analyzed, and reported (Oakley et al. 2003).

## 1.1 Background and History

The continued preservation of National Park Service natural resources “unimpaired for the enjoyment of future generations” presents park managers with many challenges (NPS 2006). To help meet these challenges, the Natural Resource Inventory and Monitoring Program (I&M) was established by congressional mandate in 1998 (NPS 1999). This program was established, in part, to help park managers establish a baseline and determine long-term trends in the composition, structure, and function of park ecosystems, and to determine how well existing management practices are sustaining those ecosystems (Fancy et al. 2009). Implementation of formalized monitoring was initiated through the establishment of 32 ecoregional networks encompassing 270 National Park System units. These networks are groups of park units linked by geography and sharing natural resource characteristics. The Mid-Atlantic Network (MIDN) was established to serve 10 national parks in Pennsylvania and Virginia spanning the Blue Ridge, Piedmont, and Coastal Plain of the mid-Atlantic region (see Figure 1 in Section 1.2 and Table 1 in Section 2.1).

Established networks were tasked with completing a series of 12 basic inventories, and selecting “vital signs” that would best represent the overall conditions of natural resources in network park units (NPS 1999). The term “vital signs” refers to a set of physical, chemical, and biological elements and processes used to track the overall condition of park natural resources (Fancy et al. 2009). To guide the process of defining and selecting vital signs for the MIDN, a Science Advisory Committee (SAC) was created. Through engagement with nearly 100 subject matter experts including park managers, academia, NGOs, and federal and state agencies, the MIDN created a prioritized list of candidate vital signs that were both relevant to network park resources, and feasible to implement given logistical and budgetary constraints (Comiskey et al. 2006). Breeding birds was ranked as high priority vital sign during the MIDN’s selection process (Comiskey and Callahan 2008) and species occurrence and distribution of birds was identified nationally as one of the 12 basic inventories needed by park staff to effectively manage their resources. Initially, it was

determined that limitations in staff time and funding would prevent the network from establishing a monitoring protocol for birds. However in 2009, with additional support from network parks, startup funding from the Natural Resources Preservation Program (NRPP), and dozens of volunteer amateur ornithologists, a pilot monitoring program was initiated at three network parks, then expanded to six parks 2011 (Table 1).

## **1.2 Landscape setting**

The Mid-Atlantic Network consists of ten parks distributed from southern Pennsylvania to southern Virginia. They range from predominantly small, cultural parks with a limited history of natural resource monitoring, to the comparatively large Shenandoah National Park (NP) (Comiskey and Callahan 2008). Using the Bird Conservation Regions (BCRs) developed by the North American Bird Conservation Initiative (NABCI)(USNABCI Committee 2000), MIDN parks range across four distinct ecological units (Figure 1). The majority of the parks, including Appomattox Court House National Historical Park (APCO), Booker T. Washington National Monument (BOWA), Eisenhower National Historical Site (EISE), Fredericksburg and Spotsylvania National Military Park (FRSP), Gettysburg National Military Park (GETT), Hopewell Furnace National Historical Site (HOFU), and Valley Forge National Historical Park (VAFO) fall within the Piedmont BCR. Richmond National Battlefield Park (RICH) falls in the far southwestern portion of the New England/Mid-Atlantic Coast BCR, Petersburg National Battlefield (PETE) is in the northern portion of the Southeastern Coastal plain BCR, and only one park, Shenandoah NP (SHEN), lies within the Appalachian Mountain BCR. Bird monitoring in the Appalachian BCR and Shenandoah NP is not covered by this protocol.

The Piedmont BCR is characterized by its rolling topography with oak-hickory dominated forests to the north and pine forests to the south. It has a long history of logging, agriculture, and other anthropogenic disturbances leading to a patchwork of secondary forests and pastures which provide breeding habitats for about 138 avian species (Kearney 2003, Watson 2014). The New England/Mid-Atlantic Coast BCR lies entirely within the Atlantic Coastal Plain, and is abundant in rivers, bays, and their associated wetlands. While most of the 134 priority species in this region are associated with these coastal ecosystems, some require the upland forested ecosystems more typical of the area surrounding Richmond National Battlefield Park (Steinkamp 2008). Similar to the Piedmont, the Southeastern Coastal Plain landscape has been heavily altered since European settlement. It contains a mixture of upland forest, forested wetlands, and permanently flooded rivers and streams supporting approximately 180 avian species (Watts 1999).

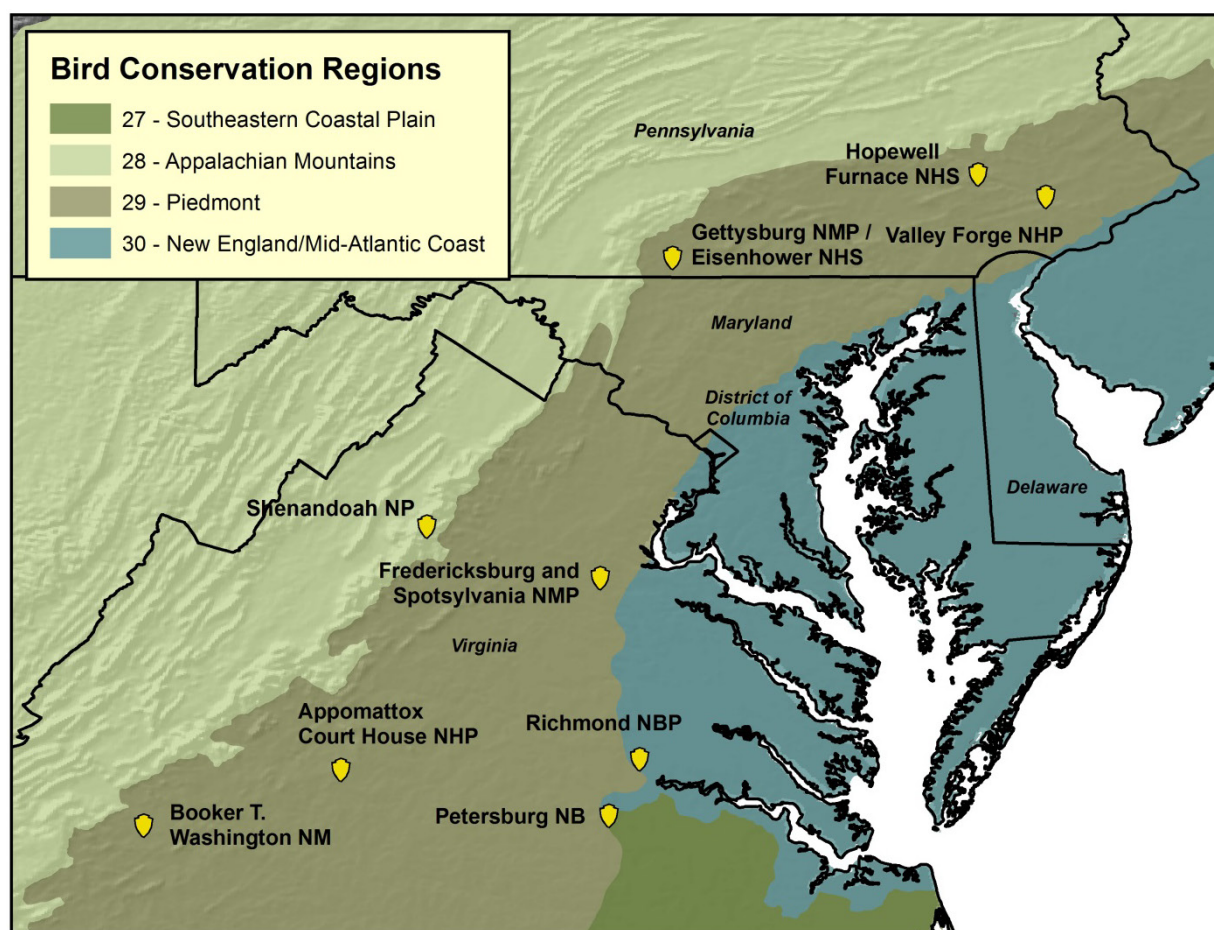


**Figure 1.** Map of Mid-Atlantic Network parks and associated Bird Conservation Regions.

### 1.3 Rationale for Monitoring Breeding Birds

With the close proximity of MIDN parks to major metropolitan areas such as Washington, D.C., Baltimore, MD and Philadelphia, PA, the primary threat to the avian community in the Mid-Atlantic region is suburbanization and the associated habitat fragmentation and loss (Rosenberg et al. 2016). At the same time, park landscapes face increased browse pressure from white-tailed deer (*Odocoileus virginianus*), invasions of nonnative plants, pests, and pathogens with concurrent changes in plant communities that can affect habitat structure, condition, and composition, reducing habitat quality for some bird species (McShea and Rappole 2000). Currently, the area between Baltimore south to Richmond and east to Norfolk is one of the fastest growing regions in North America and approximately 38% of the avian species in this region face declining population trends (Watts 1999).

National parks provide a degree of refuge from such threats, containing contiguous and protected tracts of habitat suitable for breeding birds. Many MIDN parks host bird species that are declining throughout their range (Root and Weckstein 1995, Keller et al. 2000), and all currently have species of concern breeding within the park (Rosenberg et al. 2016). The Piedmont even supports the largest population of grasshopper sparrows, a species of concern, in the northeast (Kearney 2003), but conversion of agricultural lands to suburban developments jeopardizes their status. Land use change

of any kind, either within a park, or outside its boundaries, can ultimately influence park resources. Suburban development adjacent to parks, for example, may lead to increased deer browse, introduction of exotics, and increased visitor pressure creating less desirable breeding habitat for birds (McShea and Rappole 2000).

Breeding birds have been extensively studied, and exhibit numerous characteristics that support their use as cost-effective ecological indicators (O'Connell et al. 2000). Monitoring both spatial and temporal patterns in the occurrence (i.e., occupancy and abundance) of select bird species or specific guilds known to respond to landscape or smaller-scale changes may serve as indicators of forest, stream, watershed, and park conditions. Birds are also good indicators of local and regional ecosystem changes because of their high body temperature, rapid metabolism, and occupancy of high trophic levels (Faccio et al. 2015). Additionally, the sensitivity of neotropical-migratory songbirds (i.e., warblers, tanagers, and vireos) to habitat fragmentation make them excellent barometers of environmental change (Yahner 2000). Timely detection of changes in bird population trends may help alert park staff to the presence of ecological stressors and help evaluate and guide future park management actions.

Lastly, citizen scientist programs, like this one, provide an opportunity for parks and park visitors to share in the stewardship of park lands. It facilitates engagement between participating parks and the visiting public and establishes a volunteer base with the interest and expertise needed to help the park implement the program. This collaboration is critical to the program, which lacks the funding to execute the protocol with NPS staff alone.

#### **1.4 History of Breeding Bird Monitoring in MIDN Parks**

Most MIDN parks do not have a history of breeding bird monitoring. Fredericksburg and Spotsylvania NMP, Appomattox Court House NHP, and Shenandoah NP have U.S. Geological Survey (USGS) Breeding Bird Survey routes running through or around their boundaries, but most are not regularly surveyed. Between 1993 and 2003, Shenandoah NP also ran several Monitoring Avian Productivity and Survivorship (MAPS) stations to provide annual indices of adult population size and post-fledging productivity, as well as estimates of adult survivorship and recruitment into the adult population. However, the program was discontinued in 2004 due to lack of funding. Between 1999 and 2001, bird inventories were conducted in the Pennsylvania parks (EISE, GETT, HOFU, and VAFO; Yahner et al. 2001). The Virginia parks, with the exception of Shenandoah NP, completed bird inventories in 2003 and 2004 (Bradshaw 2007a, b, 2008, NPS 2009a, b). In 2009, the MIDN, with funding from NRPP, initiated pilot testing of a breeding bird monitoring program in three of the network parks (BOWA, FRSP, and VAFO). By 2011, the program had expanded to 6 parks (Table 1), with the goal of implementing a long-term monitoring program network-wide. A detailed review of the pilot data was conducted in 2015 to evaluate sampling design, observer bias, power to detect changes in species and bird conservation indices, and the MIDN's ability to meet the targeted protocol objectives stated below (Shriver and Ladin 2016). As of 2018, data collection continues at five of the six parks.

### **1.5 Protocol Objectives**

1. Estimate status and long-term trends in species composition, occupancy, and other indices of abundance for breeding bird populations within MIDN parks.
2. Estimate status and trends in measures of biotic integrity (Bird Community Indices) for breeding bird communities within MIDN parks.
3. Evaluate changes in bird populations in forest and grassland habitats relative to park management regimes.

## 2. Sampling Design

The sampling design for this protocol was developed in cooperation with park NRM to determine their management needs, and the feasibility of long-term park collaboration. The design incorporates seven years of pilot data, a detailed analysis of the pilot protocol, and consideration of logistics and budget. This section provides an overview of the rationale behind the chosen sampling design, the target population to be monitored, and the process of site selection, sampling frequency, and a summary of our power analysis.

### 2.1 Sampling Design Rationale

A variety of sampling approaches have been used to monitor the status and trends of breeding birds throughout North America. The most widely used quantitative method for monitoring landbird populations is the point count survey (Ralph et al. 1995, Rosenstock et al. 2002). Point count surveys utilize a standardized methodology (Ralph et al. 1995) to record all birds seen or heard during a fixed amount of time at specific point locations. The resultant counts can be used to estimate landbird distribution, diversity, and abundance. Using this common sampling approach will allow us to employ the substantial literature on field methods and data analysis, and to make comparisons to other avian monitoring programs (Dawson and Efford 2013, Faccio et al. 2015, Marshall et al. 2016, Sauer et al. 2017).

Variables such as observer differences, species behavior or appearance, and environmental factors influence whether or not a bird is detected. Accounting for these variables by assessing detection probability is essential for accurately estimating common bird population metrics like occupancy, abundance, and density (Rosenstock et al. 2002, Thompson 2002, Alldredge et al. 2007). At least four methods have been proposed for estimating detection probability: double-observer (Nichols et al. 2000), double-sampling (Bart and Earnst 2002), distance-sampling (Buckland et al. 2001), and removal modeling (Farnsworth et al. 2002). Each method has its own set of advantages and disadvantages and none provide a perfect fit for point counts. However, all are believed to provide less-biased estimates than unadjusted point counts (McCallum 2005).

Sampling methods like double-observer, which requires two independent observers at each point count, and double-sampling, requiring two differing sampling methods for each point, are labor intensive and more resource-demanding than distance-sampling and removal modeling. They require twice as much field effort than other methods, doubling the human resources required and effectively reducing the potential sample size by half. Distance-sampling and removal modeling can be performed by a single observer, but each requires additional training for observers, and has sets of assumptions that independently may be difficult to meet. Furthermore, recent studies have shown that observers often cannot accurately estimate distances (Alldredge et al. 2007, Simons et al. 2007), especially in forested habitats where most detections are aural and where vegetation structure may affect an observer's ability to detect bird vocalizations (Pacifi et al. 2008). Additionally, Bayesian hierarchical modeling (Royle and Dorazio 2008) has been gaining attention as an improved method for estimating animal abundance. Hierarchical modeling augments the models of detectability from the methods above by incorporating models of spatial variation (e.g. spatially correlated

environmental or observer effects) and hence better accounting for variability in the dataset which would otherwise mask differences in space and time. Although hierarchical modeling may provide more precise estimates of abundance, it requires repeated sampling occasions in a given sampling year to estimate within year variability.

After reviewing the available sampling methods and conducting pilot testing, we decided to use procedures that would meet our objectives, but not be so complex as to be logistically infeasible. The majority of field observers will be volunteer ornithologists, so methods need to be easy to train, and easy to learn and apply. Additionally, volunteer resources are often limited, and maintaining a consistent level of volunteer effort, year over year, can be difficult. Given these constraints, methods designed for distance-sampling and removal modeling are the most feasible and will enable the network to gather data from a larger sample than double-observer and double-sampling methods. For this protocol we use a hybrid approach of these two methods (Farnsworth et al. 2005, Dawson and Efford 2013, Faccio et al. 2015) which relaxes some of their assumptions. See SOP 4 - Conducting Unlimited Radius Point Counts for the list of statistical assumptions for the sampling methods employed in this protocol. Distances are estimated using two distance bands ( $<50\text{m}$  and  $\geq 50\text{m}$ ), which allows for density estimation using the half-normal binomial distance model (Buckland 1987, Buckland et al. 2001). Although meeting the assumptions of distance modeling may prove difficult, recording distance bands allows the resulting data to be subset by distance for comparison with similar studies (Alldredge et al. 2007). Additionally, using only two distance classes simplifies the task of measuring distance and is much easier for observers to learn, reducing the training effort needed.

Each point count is 10 minutes in length and broken into 1-minute intervals. Individual observations (birds or flocks) are recorded in both the distance band and time interval where first detected. Observers will make a minimum of two visits to each point per sampling year. Collecting data in this manner allows for estimation of detection probabilities through removal modeling and provides flexibility for comparing data with other data collected under other protocols (e.g. North American Breeding Bird Survey). Additionally, using repeat visits to each point in a given breeding field season provides the framework for hierarchical modeling of occupancy and detection probability, and also improves our power to detect change over time (See 2.5 Power Analysis).

## **2.2 Target population**

The target population is restricted to breeding bird communities at each of the participating network parks or park units being sampled. Sampling is limited to the breeding season (May 25 to July 15), and includes all forested and grassland habitats in the area selected for monitoring. North American resident and Neotropical migratory bird species of the Orders Passeriformes (perching birds, including songbirds) and Piciformes (woodpeckers) constitute the majority of the target population. During pilot testing, detections of nocturnal raptors (Strigiformes), diurnal raptors (Accipitriformes), waterfowl (Anseriformes), and turkey and grouse (Galliformes) did occur, but they constituted less than 1% of all detections, effectively precluding these groups from any meaningful status and trend analyses.

We consulted with park NRM staff to determine how best to sample each network park. We assessed their areas of interest and expected level of volunteer effort to define a sampling regime that would address the park's needs, the protocol objectives, and match the level of available volunteer effort. For parks containing multiple units that are, on the whole, too large to be adequately sampled due to limitations in volunteer effort, a single unit was chosen for monitoring (Table 1). Some MIDN parks expressed interest in participating, but did not currently have the NRM staff resources to participate, or had competing priorities that prevented participation or experienced difficulty engaging a consistent cadre of volunteers to conduct the monitoring. If conditions at these parks change, they may be included in future sampling where possible.

### **2.3 Site Selection**

Within each park or park unit being sampled, sampling locations or "points" were selected as described in Standard Operating Procedure (SOP) 1 - Site Selection and Plot Establishment. Using a Geographical Information System (GIS), permanent sampling locations were selected by overlaying a 250-m grid on park maps. The grid is similar to that used for selecting vegetation monitoring plots (Comiskey et al. 2009), but offset by 125m. This allows for potential point count locations to be co-located with vegetation monitoring plots, but reduces trampling or otherwise influencing vegetation monitoring data from repeat visits.

Network parks are primarily forested, but many also contain large battlefields managed as grasslands. Park managers are interested in long term trends for both of these habitat types. Therefore, each point is categorized as either forest or grassland based on vegetation maps available for each park. Edge buffers between habitat types are not applied because interest is on the overall characterization of each habitat type rather than a comparison across types (Ralph et al. 1993).

Potential sampling locations are further reduced using a GIS by excluding points meeting the following criteria:

1. less than 15 m away from hiking trails to avoid visitor interruption of counts;
2. less than 50 m away from primary roads (e.g. interstates and major highways) which may influence bird behavior and can reduce detection ability due to background noise;
3. less than 15 m away from secondary and tertiary roads (e.g. local or park roads);
4. less than 50 m from buildings which are frequented by visitors and may influence bird behavior; and,
5. less than 50 m from the park boundary to restrict the study to habitats that are managed by the park.

Furthermore, points that may be potentially hazardous to observers (e.g. steep slopes, extremely dense forests) or that were located in archeological sites are excluded from some parks (i.e. VAFO and APCO). All available remaining points were further assessed in the field for sampling suitability and, if approved, received field markings according to SOP 1 - Site Selection and Plot Establishment.

We consulted with each park to determine how best to survey their available monitoring points during the pilot testing phase. FRSP, PETE, and RICH contain several discrete park units separated over large areas. To maximize volunteer time, resource managers at these parks selected one unit for monitoring that was of particular management concern, or thought to be most representative of their park. During pilot testing, these units were considered small enough to sample all available suitable points. BOWA is the smallest park in the network, and has a good volunteer base, so all potential plots were sampled during pilot testing. VAFO, however, is a large contiguous park with more possible sampling locations than available volunteers. Therefore, points at this park were randomly selected using the Generalized Random Tesselation Stratified (GRTS) algorithm (Stevens and Olsen 2004) to reduce the number of points, while maintaining a spatially balanced design. APCO, like VAFO, is a large contiguous park, but due to severe limitations in available volunteers and the difficulty of accessing points in dense thickets, a GRTS sample was not logistically feasible. Therefore, only targeted stations that were easily accessible were sampled at this park. Due to difficulties in recruiting an adequate volunteer base, monitoring ceased at APCO in 2012.

Results of many years of pilot testing, feedback from volunteers and park resource staff, and the results of the 2015 pilot protocol review, lead to a re-evaluation of the point selection and sampling regime at BOWA, FRSP, PETE, and RICH. Sampling all available points at these units resulted in long survey routes for volunteers with many points only being sampled once throughout a field season. This limited our ability to capture seasonal variation in detection probability and adversely affected our ability to detect change over time (Shriver and Ladin 2016). The results of our power analysis suggested that we should conduct counts at our sampling points no less than twice per season to improve our estimates. In consultation with NRM staff, we reduced the number of points sampled by approximately half at these four parks using the GRTS algorithm, allowing the same volunteer effort to capture two visits instead of one. Additionally, based on feedback from field observers, a few points were rejected at each park from future sampling due to safety or other logistical concerns. These points were replaced using the next available points in the GRTS draw results. Table 1 provides details of the sampling selection process for each park that was pilot tested. More details regarding the sampling points and maps of each participating park are provided in Appendix A.

**Table 1.** List of Mid-Atlantic Network parks displaying their participation status in the Breeding Bird Monitoring Program and their associated sampling frames. GRTS refers to the use of the Generalized Random Tesselation Stratified (GRTS) algorithm used to subsample a grid of potential sampling points. Targeted refers to points chosen for ease of access due to logistical concerns.

| Park  | Area of Inference             | Pilot Tested | Monitoring Initiated | Sampling Selection Process                                                                                                                                                                                                                                                                                                                         |
|-------|-------------------------------|--------------|----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| APCO* | Point Level                   | Yes          | 2010                 | 3 years of pilot testing sampled 32 targeted points. Due to a lack of volunteer availability, sampling discontinued in 2012.                                                                                                                                                                                                                       |
| BOWA  | Park Wide                     | Yes          | 2009                 | 7 years of pilot testing sampled all available grid points. To increase the number of yearly visits to each point, a GRTS sample of the original grid of approved sampling points reduced the number of points from 16 to 10.                                                                                                                      |
| EISE  | –                             | No           | No                   | –                                                                                                                                                                                                                                                                                                                                                  |
| FRSP  | Spotsylvania Battlefield Unit | Yes          | 2009                 | 7 years of pilot testing sampled all available grid points. To increase the number of yearly visits to each point, a GRTS sample of the original grid of approved forest sampling points reduced the number of points from 59 to 36. The 8 grassland points were not subsampled in order to maintain a sufficient sample size for this point type. |
| GETT  | –                             | No           | No                   | –                                                                                                                                                                                                                                                                                                                                                  |
| HOFU  | –                             | No           | No                   | –                                                                                                                                                                                                                                                                                                                                                  |
| PETE  | Eastern Front Unit            | Yes          | 2011                 | 3 years of pilot testing of all available grid points. To increase the number of yearly visits to each point, a GRTS sample of the original grid of approved sampling points reduced the number of points from 71 to 36.                                                                                                                           |
| RICH  | Malvern Hill Unit             | Yes          | 2010                 | 6 years of pilot testing sampled all available grid points. To increase the number of yearly visits to each point, a GRTS sample of the original grid of approved sampling points reduced the number of points from 70 to 34.                                                                                                                      |
| SHEN  | –                             | No           | No                   | –                                                                                                                                                                                                                                                                                                                                                  |
| VAFO  | Park Wide                     | Yes          | 2009                 | 7 years of pilot testing of a GRTS sample of available grid points.                                                                                                                                                                                                                                                                                |

\* Appomattox Court House National Historical Park ceased participation in 2012.

## 2.4 Sampling Frequency and Replication

Point counts are conducted yearly between May 25 and July 15. During pilot testing, 2009-2015 sampling each point once was required by observers, and additional visits were only encouraged, not required. As stated above, this resulted in survey routes too long for individuals to complete easily in

one visit, and lead many volunteers to not complete a second visit. Based on the power analysis outlined below, we determined that reducing the number of survey points would allow us to spread our volunteer effort across multiple visits and, in doing so, increase our power to detect change. Additionally, though conducting one point count per season is the minimum requirement for estimating metrics like density and species richness, it precludes the ability to estimate occupancy, and reduces precision in any modeled population estimates. As a result, field staff and volunteers are now required to complete two visits of each point and NRM staff are responsible for making sure that sampling by volunteers is balanced across sampling points in a given field season. For example, once a volunteer samples their assigned points twice, any additional effort will be assigned to points that have not yet been sampled twice. These repeat visits in a sampling season are spaced at least two weeks apart, and capped at a maximum of 4 visits per season.

## **2.5 Power Analysis**

The ability of our monitoring program to detect changes in bird populations depends on the number of sampling stations, the frequency of sampling, the quantity and dispersion of birds, and each species' likelihood of detection. To evaluate this protocol's ability to detect population changes, the MIDN initiated a cooperative agreement with the University of Delaware to evaluate and review our existing avian monitoring protocol in 2015 (Shriver and Ladin 2016). Subsequent to this report, additional analyses using data from 2009 to 2017 field seasons were used to estimate our power to detect temporal trends in both the probability of site occupancy and bird abundance in both forest and grassland habitats (Appendix B). Data from both forest (N = 230) and grassland (N = 84) survey locations within the six participating MIDN park units were used in the power analysis. Additionally, we estimated our power to detect changes in forest bird communities within the parks, using the bird community index (BCI) developed by O'Connell et al. (2003) for the Mid-Atlantic and Coastal Plain.

Estimates of species occupancy, abundance (i.e., number of individuals per sampling location) and detection probability for 128 species (Appendix C, Table C1) were generated using the 'unmarked' package (Fiske and B. Chandler 2011) in program R (R Development Core Team 2011). A power analysis was run for both forest and grassland habitat types for each participating park. To determine our ability to detect changes in species occupancy and abundance over time, we used the 'power.t.test' function of the 'pwr' package in program R following the methods outlined in Cohen (1988). Four sampling frameworks of 5-, 10-, 15- and 20-year annual sampling designs were used to illustrate the effect of additional sampling years on power. We set the desired power to 0.75 and significance to alpha level 0.05, and ran separate analyses to estimate power to detect a 10% or 50% decline in species occupancy and abundance for each of the sampling frameworks and for both habitat types (forest and grassland). The same procedures were applied to the BCI scores for each of the MIDN park units sampled. For more details regarding power analysis procedures, see Appendix B.

Assessing power at multiple scales gives us a greater understanding of the protocol's ability to assess changes at the species and community levels. Results of the power analysis on species occupancy and abundance show that we achieved power estimates greater than 0.75 for many species tested, in

both forest and grassland habitats (See Appendix B, Table B1, Table B2). In general, the power to detect a change in trend increases as both the magnitude of change and duration of monitoring increases. Our results bear this out, as we estimate greater power to detect declines of both 10% and 50% with more years of sampling. Our power to detect changes in the probability of site occupancy was much higher than for abundance and we should be able to detect changes for more species and over shorter monitoring periods than abundance. We consider these power estimates to be conservative, since species estimates were broken out by habitat, which reduces the number of detections used to assess power. We expect estimates generated by using all species observations for a park would yield even greater power to detect changes in occupancy and abundance. Results of the power analysis of park BCI scores estimate a strong power to detect declines (See Appendix B, Table B3). For the five parks currently participating in monitoring efforts, we estimate the ability to detect a 10% decline with a power  $>0.90$  under all monitoring durations.

### 3. Field Methods

Avian monitoring described in this protocol occurs annually from May 25th through July 15th. Successful completion of the field sampling portion of the protocol requires advanced planning by MIDN and Natural Resource staff at participating parks. These activities include: preparation of field equipment, route maps, field forms, volunteer recruitment, and training of field staff and volunteers. Details on each of these activities are described in the Personnel Requirements and Training section below and associated protocol Standard Operating Procedures (SOPs) listed in Table 2.

**Table 2.** List of supplemental and Standard Operating Procedure documents for avian monitoring in the MIDN.

| Title                                                  | SOP #          |
|--------------------------------------------------------|----------------|
| Quality Assurance Plan*                                | Not Applicable |
| Safety Plan                                            | Not Applicable |
| Site Selection and Plot Establishment                  | 1.0            |
| Preparations and Equipment Setup Prior to Field Season | 2.0            |
| Volunteer Recruitment and Training                     | 3.0            |
| Conducting Unlimited Radius Point Counts               | 4.0            |
| Volunteer Manual and Field Datasheets                  | 5.0            |
| Using the Global Positioning System (GPS)              | 6.0            |
| Using the stopwatch                                    | 7.0            |
| Data Entry and Analysis Database                       | 8.0            |
| Data Management                                        | 9.0            |
| Data Analysis and Reporting                            | 10.0           |

\* In lieu of a published Quality Assurance Plan, please reference the Data Quality Standards document.

#### 3.1 Field Preparations and Scheduling

Because the bird monitoring protocol is a volunteer-based program, and because park resource managers are most familiar with the local birding community, preparations for the field season must be a joint effort with the network protocol lead and park resource managers. Prior to the field season, the protocol lead prepares field forms, volunteer manuals, and any recent summaries or reports and sends materials to the park resource manager. The park resource manager contacts, recruits, and coordinates volunteers. Depending on the park, the park resource manager or the protocol lead inventories, organizes, and prepares field equipment for volunteer pick-up. Additional details and a full list of equipment are provided in SOP 2 - Preparations and Equipment Setup. Within one month

prior to the beginning of the field season, the protocol lead holds training sessions for new and returning volunteers on the field methods for conducting the protocol.

### **3.2 Field Sampling Methods**

Sampling stations are selected as outlined above (see Section 2.3 Site Selection) and have been marked according to each park's preferred method of marking points. Volunteers are encouraged to visit their sampling locations prior to performing point counts to familiarize themselves with the area and the type of birds present. Point counts must occur between sunrise and 5 hours after (typically between 5:30 – 10:30am). Upon arrival, volunteers begin by recording the environmental conditions (i.e. sky, wind, temperature, and noise conditions) on their field mapping card, while allowing time for birds that may have been flushed to return. During the point count, volunteers record the species, type of detection, time interval, and distance band of birds encountered. Detailed methods and field procedures are provided in SOP 4 (Conducting Unlimited Radius Point Counts) and SOP 5 (Volunteer Manual and Field Datasheets).

### **3.3 Post-Collection Processing**

At the end of the field season, volunteers are contacted to ensure they have returned all field equipment and datasheets in a timely manner. Datasheets are sent to the protocol lead for quality assurance and quality control review. All data are entered into the master database and field forms are scanned and archived (detailed in section 4).

## **4. Data Management**

### **4.1 Overview of Database Design**

Bird monitoring data from 2009-2013 was entered and stored in the SQL-server based USGS Point Count Database, hosted and managed by the USGS Patuxent Wildlife Research Center in Laurel, MD. This online repository for point count data was migrated to the Avian Knowledge Network in 2014. It was decided for the 2015 field season, that the MIDN would migrate their data to a local MS Access application that would allow for greater control over the data. This application is based on a modified version of the USGS SQL-server backend which contained three core tables that housed field data. The first table hosts sampling location data, the second contains survey information including the observers, date, time, and environmental factors, and the third holds observation data including the species, distance band, detection type, and counts. Finally, species, contacts, and attribute look-up tables provide standardized values for data fields to minimize data entry errors. The front end database is designed for ease of data entry and each field has validation rules in place to check values as they are entered to prevent typographic and logic errors.

### **4.2 Data Transcription, Entry, and Validation**

Observers transcribe all records from their field mapping cards directly to field data forms, which allow for ease of data entry. All forms are then entered into the MIDN's Access database by MIDN staff or trained volunteers. During each transcription step, responsible parties must review 100% of the records entered to ensure data has been transferred accurately and completely before moving to the next field form. The front end forms of the database are designed for ease of data entry, and each data entry field has coded validation rules in place to check each value as they are entered to prevent typographic and logic errors. Detailed instructions for entering data into the database may be found in SOP 8 - Data Entry and Analysis Database.

After the field data have been entered, they are reviewed for quality, completeness, and logical consistency. MIDN staff or trained volunteers review 100% of the records entered to ensure that values present on field forms were accurately and completely transcribed into digital form. An effort is made to prevent the same staff member, who entered the data, from conducting the 100% verification check. Ten percent of records are reviewed a second time by either the protocol lead or designated staff. All comments and changes to the data sheets should be annotated with the initials of the staff member making the change. The protocol lead goes over any changes before they are completed. If a significant transcription error (e.g., incorrect values or missing records) is found in one out of 10 datasheets during the 10% review, then the entire data set is verified again (i.e., repeat the 100% and subsequent 10% checks until the protocol lead is satisfied with the data quality).

A series of Quality Control checks are run by the protocol lead or designated staff on the aggregated data using SQL or R code and, again, is checked for completeness and logical consistency. The errors found and all actions taken are documented and placed on the network server.

### **4.3 Data Certification and Archiving**

Upon completion of all data review activities, the Protocol Lead, or designated staff, compile all raw and processed data and associated metadata. Seasonal closeout procedures documented in Standard

Operating Procedure 9: Data Management should be followed. All original Field Mapping Cards and Field Forms are scanned to Adobe PDF format, and the paper copies filed in the MIDN office. Scanned field forms are placed on to the network server along with the final MS Access database, relevant spatial data, and any additional documentation created throughout the field season. More information on data management, data validation, and archiving may be found in SOP 9 - Data Management.

## 5. Data Analysis and Reporting

Two types of reporting will be produced with data collected under this protocol: annual data summaries and multi-year synthesis reports. Any long form reports will be published in the NPS's Natural Resources Publication Series (<http://www.nature.nps.gov/publications/nrpm/>). The Natural Resource Report (NRR) series and Natural Resource Data Series (NRDS) are used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the NPS mission. All manuscripts in the series must adhere to a set of minimum standards and are peer-reviewed to ensure that information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

### 5.1 Annual Data Summaries

Annual data summaries describe the year's survey effort, and provide general population and community level statistics at the network and park levels. Yearly topics of interest may also be included in resource briefs, which can be used as outreach items for each park and volunteers. Each annual summary will also provide a brief description of methods used to collect and assess data. As outlined in SOP 10 - Data Analysis and Reporting, metrics to be included in annual data summaries include species counts (e.g. species richness), counts of Partners in Flight (PIF) species of concern, relative abundance, and percent occurrence. Annual summaries will also include scorecards of ecological integrity based on bird community assessments. Bird community assessments or indices (BCIs) yield a quantitative metric that may be used to define the ecological integrity of an area based on the avian community. The BCI developed by O'Connell et al. (2003) is suitable only for forest points. The MIDN continues to evaluate the best methods for analyzing the communities in our grassland habitats. Where possible, methods for automating the production and publication of yearly data summaries will be used. As the availability of data visualization technology improves, the MIDN will utilize interactive visualization tools to make data available to the NRM staff in lieu of the static reports of the NRDS publication series.

### 5.2 Multi-year Synthesis Reports

The network will start producing multi-year synthesis reports addressing detectability, site occupancy, and population trends once ten complete years of data have been collected and a code base for analysis has been developed by the network or in cooperation with network partners. These reports will be updated every 5 years. Various statistical methods and software packages have been developed to estimate population densities while accounting for detection probability including program DISTANCE (distance sampling) (Thomas et al. 2010), program MARK (removal modeling) (White and Burnham 1999), and the "unmarked" package in program R (hierarchical modeling) (Fiske and Chandler 2011). Because a minimum of 80-100 detections of each species per observer are needed in order to calculate detection probabilities, and observer effects on detection probability, several years of data collection will be needed for all but the most common species (Bibby et al. 1998). When enough data have been collected, an analysis of factors influencing detection rates will be conducted and measures of species composition, site occupancy, and trends in these metrics will

be estimated using the best available statistical methods and software packages. For more details regarding planned analyses, see SOP 10 - Data Analysis and Reporting.

## 6. Personnel Requirements and Training

### 6.1 Roles and Responsibilities

The Mid-Atlantic Network bird monitoring protocol is coordinated by the designated protocol lead in consultation with the network program manager. Because the majority of the fieldwork is conducted by volunteers, park Natural Resource Managers play an active role in recruiting and coordinating volunteers. Roles and responsibilities for this protocol are displayed below in Table 3.

**Table 3.** Roles and responsibilities for avian monitoring in the MIDN.

| Role                       | Responsibilities                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Protocol Lead              | <ul style="list-style-type: none"><li>• Implements avian monitoring program and provides oversight, administration, and budget tracking</li><li>• Liaison to Washington Support Office (WASO) programs, offices, and other I&amp;M networks, and NRM staff at participating parks</li><li>• Prepares for field season including training field staff and volunteers</li><li>• Assumes primary responsibility for data analysis and reporting</li><li>• Assists data manager with data certification.</li><li>• Coordinates data requests with Data Manager</li><li>• Coordinates yearly protocol review and any revisions</li></ul> |
| Natural Resource Staff     | <ul style="list-style-type: none"><li>• Provides safety instruction and park contact information</li><li>• Prepares field equipment</li><li>• Recruits volunteers and coordinates park training schedule with protocol lead</li><li>• Manages volunteer sampling effort</li><li>• Oversees return of field equipment and completed data forms</li></ul>                                                                                                                                                                                                                                                                             |
| Field Staff and Volunteers | <ul style="list-style-type: none"><li>• Attends provided protocol training</li><li>• Coordinates with Park NRM staff to complete field survey work</li><li>• Returns equipment and completed data sheets in a timely fashion</li></ul>                                                                                                                                                                                                                                                                                                                                                                                              |
| Data Manager               | <ul style="list-style-type: none"><li>• Advises on data and information management activities</li><li>• Develops and maintains protocol database in accordance with NPS IMD standards</li><li>• Manages GIS, GPS data and map products</li><li>• Manages data archiving and long-term data security activities</li><li>• Coordinates Data Quality review, develops data review and cleaning tools</li><li>• Posts final data, metadata, reports, and other protocol products to MIDN server, NPS data store, and network Web sites.</li></ul>                                                                                       |

### 6.2 Field staff and Volunteer Requirements

Field staff and volunteer participants completing point counts should be able to identify the avian species likely to be encountered in the Mid-Atlantic region (e.g., BCR 29: Piedmont) during the breeding season by both sight and sound, and should have at least 3-5 years of birding experience in the Mid-Atlantic region. Being able to identify birds by sound is emphasized, as the majority of bird detections in Mid-Atlantic forests are by sound. Volunteers must be capable of hiking on varied terrain and able to navigate through forests with a GPS. Volunteers are also encouraged to take an

online bird certification test specifically designed to evaluate observer skill. Park Resource Managers will coordinate and evaluate potential volunteers and novice volunteers will be paired with more experienced observers to mentor them on protocol procedures and bird identification.

### **6.3 Training**

Various studies have shown that observer bias is one of the most noteworthy confounding factors in trend analysis of songbird populations (Sauer et al. 1994, Kendall et al. 1996, Link and Sauer 1998, Alldredge et al. 2007). Both the quality and consistency of data collected can be improved, if observers are well-trained on the protocol and their identification skills are regularly tested. The yearly protocol trainings conducted by the project lead cover point-count procedures, distance estimation, equipment use, data transcription, and safety procedures (SOP 3 - Volunteer Recruitment and Training). Additionally, though volunteers and staff should already be experienced at bird identification, they are encouraged, but not required, to practice and test their abilities prior to completing field work. Details regarding available self-testing methods are provided in SOP 3.

To evaluate observer bias in data collected by this protocol, the MIDN initiated a cooperative agreement with the University of Delaware to evaluate and review our existing avian monitoring protocol in 2015. One of the goals of this protocol is to attempt to integrate our data with other networks in the Northeast region. To this end, we coordinated with the National Capital Region Network to use the same paid observers to collect data in two of MIDN's parks. Since volunteer and paid observer data collection occurred at the same points, direct comparison of the two groups was possible. This allowed us to test for any potential observer-type bias that could arise in larger-scale regional analyses using data collected across national park networks. The resulting analysis found no significant relationship between observer type and detection probability within forest or grassland monitoring points. Within forest and grassland habitat types, citizen scientists detected 16 more unique species than paid observers (Ladin et al. 2016). These results support our contention that using volunteers for breeding bird monitoring yields quality data and is comparable to other monitoring programs in North America.

### **6.4 Safety**

The Mid-Atlantic Network considers the occupational health and safety of its employees and volunteers to be of utmost importance, and is committed to ensuring that all personnel receive adequate training on National Park Service (NPS) safety procedures, incident reporting, and emergency response prior to field work. Numerous safety issues and concerns are associated with implementing a long-term, service-wide monitoring program that includes extensive fieldwork and sampling by network staff and volunteers. Field work requires an awareness of potential hazards and knowledge of basic safety procedures. Field personnel routinely come in direct and indirect contact with rough terrain, potentially hazardous plants and animals, and adverse weather conditions. Prior to going into the field, the protocol lead reviews safety procedures and job hazard analyses with all park staff and volunteers. Additionally, park natural resource staff address issues specific to their park with all volunteers and staff participating in protocol activities prior to the field season. For additional information, reference the safety procedures for this program detailed in the Safety Plan.

## 7. Operational Requirements

### 7.1 Annual Workload and Field Schedule

The avian breeding season (May-July) and associated field data collection dictates the yearly schedule of protocol activities listed in Table 4. The protocol lead oversees the implementation and coordinates with MIDN staff, Park NRM staff, and volunteers to ensure protocol objectives will be met. Further details regarding preparations for the field season are found in SOP 2 - Preparations and Equipment Setup.

**Table 4.** Yearly schedule of protocol activities for avian monitoring in the MIDN.

| Timeframe           | Participating Staff              | Activity                                                                                                            |
|---------------------|----------------------------------|---------------------------------------------------------------------------------------------------------------------|
| January - March     | Protocol Lead                    | Complete data analysis, prepare briefs, reports, or visualizations as required, discuss results with park NRM staff |
| January - March     | Protocol Lead and Data Manager   | Field Season Preparation                                                                                            |
| March - May         | Protocol lead and park NRM staff | Recruit volunteers and conduct protocol training for field staff and volunteers                                     |
| May 25 - July 15    | Field Staff and Volunteers       | Conduct point counts                                                                                                |
| September 1         | Field staff and Volunteers       | Deadline for receiving data                                                                                         |
| September - October | Protocol Lead and Data Manager   | Data entry and QAQC review                                                                                          |
| October             | Protocol Lead                    | Replacement equipment purchased                                                                                     |
| November            | All MIDN staff                   | Protocol review                                                                                                     |
| November - January  | Protocol Lead                    | Complete protocol and SOP updates as necessary                                                                      |

### 7.2 Facility and Equipment Needed

This program is based out of the MIDN office at Fredericksburg and Spotsylvania National Military Park. Field supplies are minimal, and are stored either at the MIDN office, or at each participating park under the care of their natural resource staff. Access to a MIDN vehicle is required for traveling to training activities at network parks during the months prior to the field season. A full list of equipment used in this protocol is found in SOP 2 - Preparations and Equipment Setup. Volunteers are responsible for supplying their own binoculars and vehicles needed to navigate to the park or point being sampled.

### 7.3 Operational Costs

MIDN received \$17,000 through NRPP funds in 2009 to begin pilot testing bird monitoring. The funds were used to purchase supplies for 5 network parks, travel, personnel, and a contract for initial data analysis and reporting through the University of Delaware. Since this initial support, the

protocol has been supported through the MIDN base funding. Table 5 summarizes estimated annual operational costs associated with this protocol.

**Table 5.** Estimated annual operational costs associated with the implementation of the Mid-Atlantic Breeding Bird Monitoring Protocol based on 2018 salary and benefit costs.

| Item                   | Base Salary* | %        | \$            | Notes    |
|------------------------|--------------|----------|---------------|----------|
| Protocol Lead          | \$101,035    | 15%      | 15,155        | GS-11    |
| Data manager           | \$101,035    | 10%      | 10,104        | GS-11    |
| Network Ecologist      | \$121,099    | 5%       | 6,055         | GS-12    |
| Travel - Training      | –            | –        | 1,000         | –        |
| Equipment and Supplies | –            | –        | 1,000         | –        |
| <b>TOTAL</b>           | <b>–</b>     | <b>–</b> | <b>33,314</b> | <b>–</b> |

\* based on step 5 of GS Locality Pay Tables for northern VA, cost of benefits included

## 7.4 Protocol Revision

This protocol and associated SOPs are considered a “living document”. Yearly reviews of protocol procedures, results of Quality Control reviews, and feedback from staff and volunteers, will feed into a cycle of continuous improvement. Needed revisions may not require actual changes to the protocol itself, but small changes in guidance, training and SOPs. The protocol, in its entirety, will also be subject to a thorough review approximately every five years. This will, most likely, coincide with periodic long term trend analyses. The protocol lead, delegated network staff, and, if feasible, qualified external reviewers will critically evaluate the ability of the data collected to meet stated protocol objectives. Proposed changes and potential impacts to the future interpretability, or compatibility with previously collected metrics will be weighed in any decision to revise the protocol. Decisions, rationale, scope, and impacts will be documented thoroughly in the revision logs associated with the relevant protocol documents. A new version number is assigned to the revised SOP or narrative, and each updated document is published to the data store prior to the field season. Careful documentation of changes to the protocol and SOPs, and all previous versions are essential for maintaining consistency in data collection, interpretability, and compatibility over the life of this protocol.

## 8. Literature Cited

- Allredge, M. W., T. R. Simons, and K. H. Pollock. 2007. Factors affecting aural detections of songbirds. *Ecol Appl* 17(3):948-955.
- Bart, J. and S. L. Earnst. 2002. Double sampling to estimate density and population trends in birds. *The Auk* 119(1):36-45.
- Bibby, C., M. Jones, and S. Marsden. 1998. Expedition Field Techniques: Bird Surveys. Expedition Advisory Centre, Royal Geographic Society, London, U. K.
- Bradshaw, D. 2007a. Richmond National Battlefield Park Avian Inventory. Technical Report NPS/NER/NRTR—2007/074. National Park Service, Philadelphia, PA.
- Bradshaw, D. 2007b. Appomattox Court House National Historical Park Avian Inventory. Technical Report NPS/NER—2007/088. National Park Service, Philadelphia, PA.
- Bradshaw, D. 2008. Petersburg National Battlefield Avian Inventory. Technical Report NPS/NER/NRTR—2008/108. National Park Service, Philadelphia, PA.
- Buckland, S. T. 1987. On the Variable Circular Plot Method of Estimating Animal Density. *Biometrics* 43(2):363-384.
- Buckland, S. T., D. R. Anderson, K. P. Burnham, J. Laake, D. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford.
- Cohen, J. 1988. Statistical power analysis for the behavioral sciences. L. Erlbaum Associates, Hillsdale, N.J.
- Comiskey, J. A., K. K. Callahan, and C. Davis. 2006. Mid-Atlantic Network Vitals Signs Monitoring Plan: Phase Two. Inventory and Monitoring Program, National Park Service, Fredericksburg, VA.
- Comiskey, J. A. and K. K. Callahan. 2008. Mid-Atlantic Network vital signs monitoring plan. Natural Resource Report NPS/MIDN/NRR—2008/071. National Park Service, Fort Collins, Colorado.
- Comiskey, J. A., J. P. Schmit, and G. Tierney. 2009. Mid-Atlantic Network forest vegetation monitoring protocol. Natural Resource Report NPS/MIDN/NRR—2009/119 National Park Service, Fort Collins, Colorado.
- Dawson, D. K. and M. G. Efford. 2013. Protocol for Monitoring Forest-Nesting Birds in National Park Service Parks. Natural Resource Report NPS/NCRN/NRR—2014/749. National Park Service, Fort Collins, Colorado.

- Faccio, S. D., B. R. Mitchell, and P. S. Pooler. 2015. Northeast Temperate Network Breeding Landbird Monitoring Protocol. Natural Resource Report NPS/NETN/NRR—2015/942. National Park Service, Fort Collins, Colorado.
- Fancy, S., J. Gross, and S. Carter. 2009. Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment* 151(1-4):161-174.
- Farnsworth, G. L., K. H. Pollock, J. D. Nichols, T. R. Simons, J. E. Hines, J. R. Sauer, and J. Brawn. 2002. A Removal Model For Estimating Detection Probabilities From Point-Count Surveys. *The Auk* 119(2):414-425.
- Farnsworth, G. L., J. D. Nichols, J. R. Sauer, S. G. Fancy, K. H. Pollock, S. A. Shriner, and T. R. Simons. 2005. Statistical approaches to the analysis of point count data: A little extra information can go a long way. *Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference* 2002:736-743.
- Fiske, I. and R. B. Chandler. 2011. Unmarked: An R Package for Fitting Hierarchical Models of Wildlife Occurrence and Abundance. *Journal of Statistical Software* 43(10).
- Kearney, R. F. 2003. Partners in Flight Bird Conservation Plan: The Mid-Atlantic Piedmont (Physiographic Area 10), Version 1.0.
- Keller, G. S., R. H. Yahner, G. L. Storm, B. D. Ross, R. W. Rohrbaugh, Jr., and J. F. Karish. 2000. Survey of birds in three national parks of Pennsylvania with emphasis on species of special concern. *Journal of the Pennsylvania Academy of Science* 74(1):13-18.
- Kendall, W. L., B. G. Peterjohn, and J. R. Sauer. 1996. First-time observer effects in the North American Breeding Bird Survey. *The Auk* 113(4):823-829.
- Kéry, M. 2008. Estimating Abundance From Bird Counts: Binomial Mixture Models Uncover Complex Covariate Relationships. *The Auk* 125(2):336-345.
- Ladin, Z. S., C. D. Higgins, J. P. Schmit, G. Sanders, M. J. Johnson, A. S. Weed, M. R. Marshall, J. P. Campbell, J. A. Comiskey, and W. G. Shriver. 2016. Using regional bird community dynamics to evaluate ecological integrity within national parks. *Ecosphere* 7(9):e01464-n/a.
- Link, W. A. and J. R. Sauer. 1998. Estimating population change from count data: Application to the North American Breeding Bird Survey. *Ecological Applications* 8(2):258-268.
- Marshall, M., C. J. Tzilkowski, and K. K. Callahan. 2016. Streamside bird monitoring protocol for the Eastern Rivers and Mountains Network: Protocol narrative version 3.0. Natural Resource Report NPS/NETN/NRR—2016/1224. National Park Service, Fort Collins, Colorado.
- McCallum, D. 2005. A conceptual guide to detection probability for point counts and other count-based survey methods.

- McShea, W. J. and J. H. Rappole. 2000. Managing the abundance and diversity of breeding bird populations through manipulation of deer populations. *Conservation Biology* 14(4):1161-1170.
- Nichols, J. D., J. E. Hines, J. R. Sauer, F. W. Fallon, J. E. Fallon, and P. J. Heglund. 2000. A Double-Observer Approach For Estimating Detection Probability and Abundance From Point Counts. *The Auk* 117(2):393-408.
- NPS. 1999. Natural Resource Challenge: The National Park Service's Action Plan for Preserving Natural Resources. U.S. Department of Interior, National Park Service, Washington, DC.
- NPS. 2006. Management Policies 2006. National Park Service, Washington, DC. NPS. 2009a. Inventory of Avian Species at Booker T. Washington National Monument, Virginia. Technical Report NPS/NER/NRTR—2009/137. National Park Service, Philadelphia, PA.
- NPS. 2009b. Inventory of Avian Species at Fredericksburg and Spotsylvania National Military Park, Virginia. Technical Report NPS/NER/NRTR—2009/139. National Park Service, Philadelphia, PA.
- O'Connell, T. J., R. P. Brooks, M. J. Lanzone, and J. A. Bishop. 2003. A bird community index for the Mid-Atlantic Piedmont and Coastal Plain. Final Report to the USGS Patuxent Wildlife Research Center. Report No. 2003-02, Penn State Cooperative Wetlands Center, University Park, Pennsylvania.
- O'Connell, T. J., L. E. Jackson, and R. P. Brooks. 2000. Bird guilds as indicators of ecological condition in the central Appalachians. *Ecological Applications* 10(6):1706-1721.
- Oakley, K. L., L. P. Thomas, and S. G. Fancy. 2003. Guidelines for long-term monitoring protocols. *Wildlife Society Bulletin* 31:1000-1002.
- Pacifici, K., T. R. Simons, and K. H. Pollock. 2008. Effects of Vegetation and Background Noise on the Detection Process in Auditory Avian Point-Count Surveys. *The Auk* 125(3):600-607.
- R Development Core Team. 2011. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL <http://www.R-project.org/>. Version: 2.13.2.
- Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook of Field Methods for Monitoring Landbirds. Gen. Tech. Rep. PSW-GTR-144.
- Ralph, C. J., S. Droege, and J. R. Sauer. 1995. Managing and Monitoring Birds Using Point Counts: Standards and Applications 1, 3.
- Root, T. L. and J. D. Weckstein. 1995. Changes in winter ranges of selected birds, 1901-89. Pages 386-389 in E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. *Our living resources: A report to the nation on the distribution, abundance, and health of U.S. plants,*

animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, DC.

- Rosenberg, K. V., J. A. Kennedy, R. Dettmers, R. P. Ford, D. Reynolds, J. D. Alexander, C. J. Beardmore, P. J. Blancher, R. E. Bogart, G. S. Butcher, A. F. Camfield, A. Couturier, D. W. Demarest, W. E. Easton, J. J. Giocomo, R. H. Keller, A. E. Mini, A. O. Panjabi, D. N. Pashley, T. D. Rich, J. M. Ruth, H. Stabins, J. Stanton, and T. Will. 2016. Partners in Flight Landbird Conservation Plan: 2016 Revision for Canada and Continental United States. Partners in Flight Science Committee. Partners in Flight Science Committee.
- Rosenstock, S. S., D. R. Anderson, K. M. Giesen, L. Tony, and M. F. Carter. 2002. Landbird Counting Techniques: Current Practices and an Alternative. *The Auk* 119(1):46-53.
- Royle, J. A. 2004. N-Mixture Models for Estimating Population Size from Spatially Replicated Counts. *Biometrics* 60(1):108-115.
- Royle, J. A. and R. M. Dorazio. 2008. Hierarchical modeling and inference in ecology: The analysis of data from populations, metapopulations and communities. Academic Press, San Diego, California.
- Sauer, J., D. Niven, J. Hines, D. Ziolkowski Jr, K. L. Pardieck, J. E. Fallon, and W. Link. 2017. The North American Breeding Bird Survey, results and analysis 1966 - 2015.
- Sauer, J. R., B. G. Peterjohn, and W. A. Link. 1994. Observer Differences in the North American Breeding Bird Survey. *The Auk* 111(1):50-62.
- Shriver, W. G. and Z. S. Ladin. 2016. Review and Testing of Avian Monitoring Protocols for the Mid-Atlantic and National Capital Region I&M Networks of the National Park Service. Internal report to the Mid-Atlantic Network.
- Simons, T. R., M. W. Alldredge, K. H. Pollock, and J. M. Wettroth. 2007. Experimental Analysis of the Auditory Detection Process on Avian Point Counts. *The Auk* 124(3):986-999.
- Steinkamp, M. 2008. New England/Mid-Atlantic Coast Bird Conservation Region (BCR 30) Implementation Plan. Atlantic Coast Joint Venture, Laurel, MD.
- Stevens, D. L. and A. R. Olsen. 2004. Spatially Balanced Sampling of Natural Resources. *Journal of the American Statistical Association* 99(465):262.
- Thomas, L., S. T. Buckland, E. A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology* 47(1):5-14.
- Thompson, W. L. 2002. Towards Reliable Bird Surveys: Accounting for Individuals Present but Not Detected. *The Auk* 119(1):18-25.

- USNABCI Committee. 2000. The North American Bird Conservation Initiative in the United States: a vision of American bird conservation. U.S. Fish and Wildlife Service, Arlington, Virginia.
- Watson, J. K. 2014. The Piedmont Bird Conservation Region (BCR 29) Implementation Plan. Southern Appalachian Bird Conservancy.
- Watts, B. D. 1999. Partners in Flight Bird Conservation Plan: The Mid-Atlantic Coastal Plain (Physiographic Area 44), Version 1.0.
- White, G. C. and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46(sup1):S120-S139.
- Yahner, R. H., editor. 2000. Eastern deciduous forest: Ecology and wildlife conservation. 2nd ed edition. University of Minnesota Press, Minneapolis, MN.
- Yahner, R. H., B. D. Ross, G. S. Keller, and D. S. Klute. 2001. Comprehensive Inventory Program for Birds at Six Pennsylvania National Parks. Technical Report NPS/PHSO/NRTR—01/084. U. S. Department of the Interior, National Park Service, Northeast Region, Stewardship and Partnerships, Philadelphia, PA.

## Appendix A. Maps of sampling locations

This appendix contains maps for each park currently participating in the MIDN breeding bird monitoring program. Monitoring locations are colored coded to reflect their current monitoring status and habitat type being monitored. Inactive points, marked in gray, were either excluded from monitoring for safety or logistical reasons, or were not selected during application of the Generalized Random Tessellation Stratified (GRTS) algorithm during final point selection. See section 2.3, Site Selection, for more information on the GRTS draw process. Details regarding the number of sampling locations are outlined below in Table A1.

**Table A1.** List of Mid-Atlantic Network parks currently participating in the Breeding Bird Monitoring Program and the number of sampling locations for each park.

| Park                                                       | Subunit                  | Park Code | Current Participation | Active sampling locations | Inactive sampling locations | Historical Total of sampled locations |
|------------------------------------------------------------|--------------------------|-----------|-----------------------|---------------------------|-----------------------------|---------------------------------------|
| Appomattox Court House National Historical Park (NHP)      | –                        | APCO      | No                    | 0                         | 33                          | 33                                    |
| Booker T. Washington National Monument (NM)                | –                        | BOWA      | Yes                   | 10                        | 6                           | 16                                    |
| Eisenhower National Historic Site (NHS)                    | –                        | EISE      | No                    | Not Applicable            | Not Applicable              | Not Applicable                        |
| Fredericksburg & Spotsylvania National Military Park (NMP) | Spotsylvania Battlefield | FRSP      | Yes                   | 36                        | 23                          | 59                                    |
| Gettysburg National Military Park (NMP)                    | –                        | GETT      | No                    | Not Applicable            | Not Applicable              | Not Applicable                        |
| Hopewell Furnace National Historic Site (NHS)              | –                        | HOFU      | No                    | Not Applicable            | Not Applicable              | Not Applicable                        |
| Petersburg National Battlefield (NB)                       | Eastern Front            | PETE      | Yes                   | 36                        | 35                          | 45                                    |
| Richmond National Battlefield Park (NBP)                   | Malvern Hill             | RICH      | Yes                   | 34                        | 36                          | 67                                    |
| Shenandoah National Park                                   | –                        | SHEN      | No                    | Not Applicable            | Not Applicable              | Not Applicable                        |

| Park                                  | Subunit | Park Code | Current Participation | Active sampling locations | Inactive sampling locations | Historical Total of sampled locations |
|---------------------------------------|---------|-----------|-----------------------|---------------------------|-----------------------------|---------------------------------------|
| Valley Forge National Historical Park | –       | VAFO      | Yes                   | 80                        | 80                          | 76                                    |

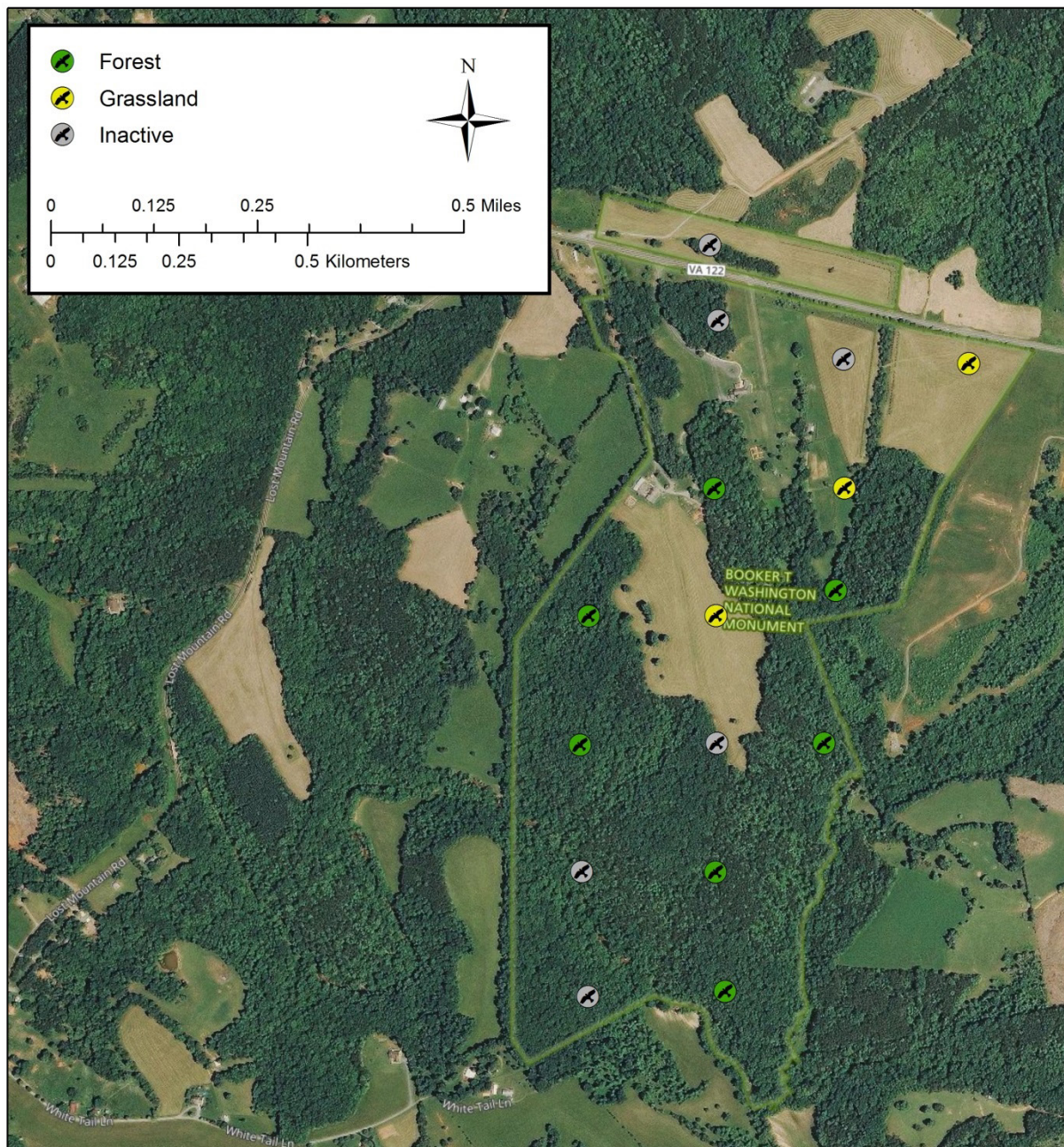


**Figure A1.** Aerial image of Booker T. Washington National Monument (BOWA) showing active forest (green) and grassland (yellow) monitoring locations. Previously monitored points that are now inactive are shown in gray.

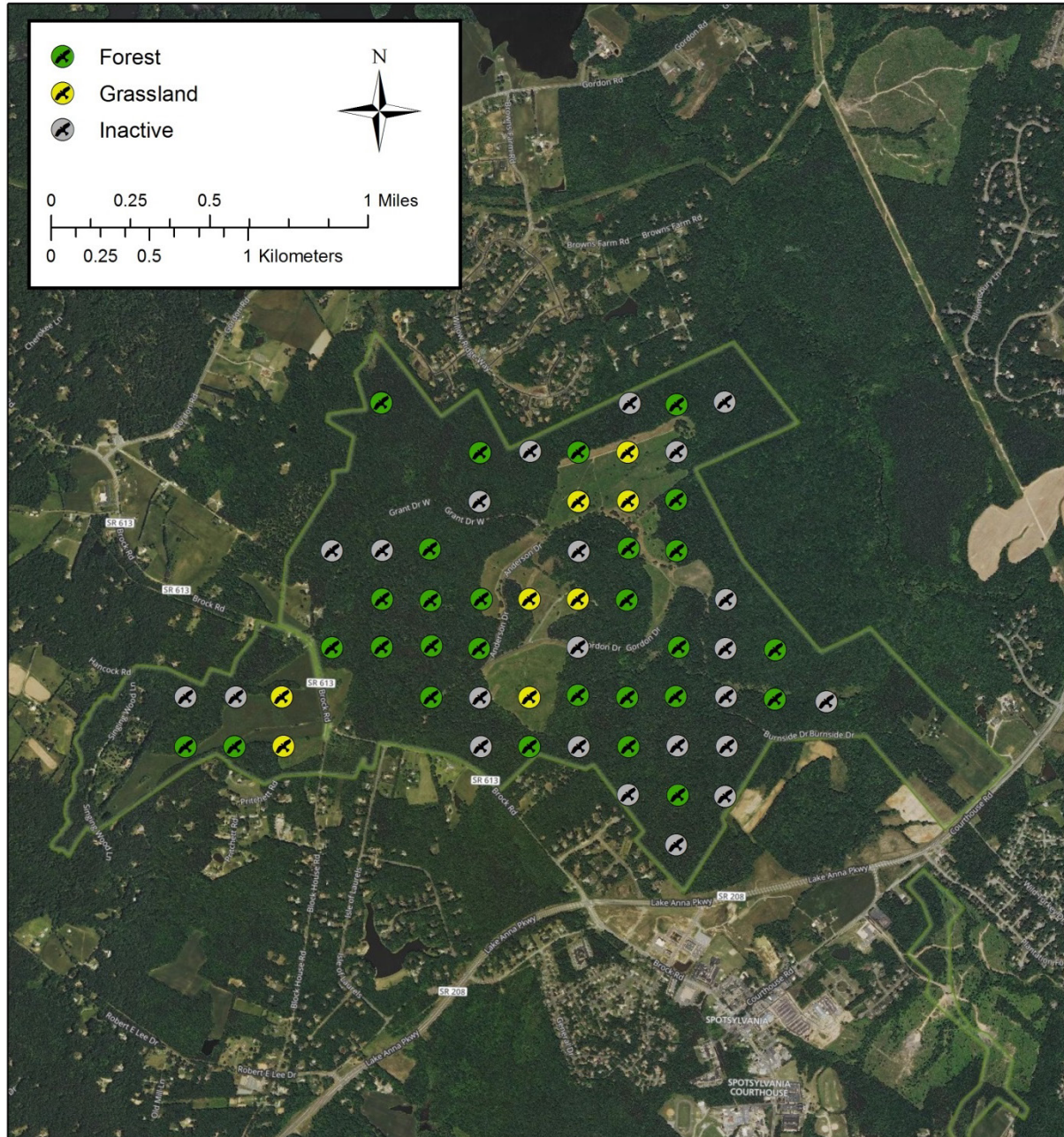


**Figure A2.** Aerial image of the Spotsylvania Battlefield Unit of Fredericksburg and Spotsylvania National Military Park (FRSP) showing active forest (green) and grassland (yellow) monitoring locations. Previously monitored points that are now inactive are shown in gray.

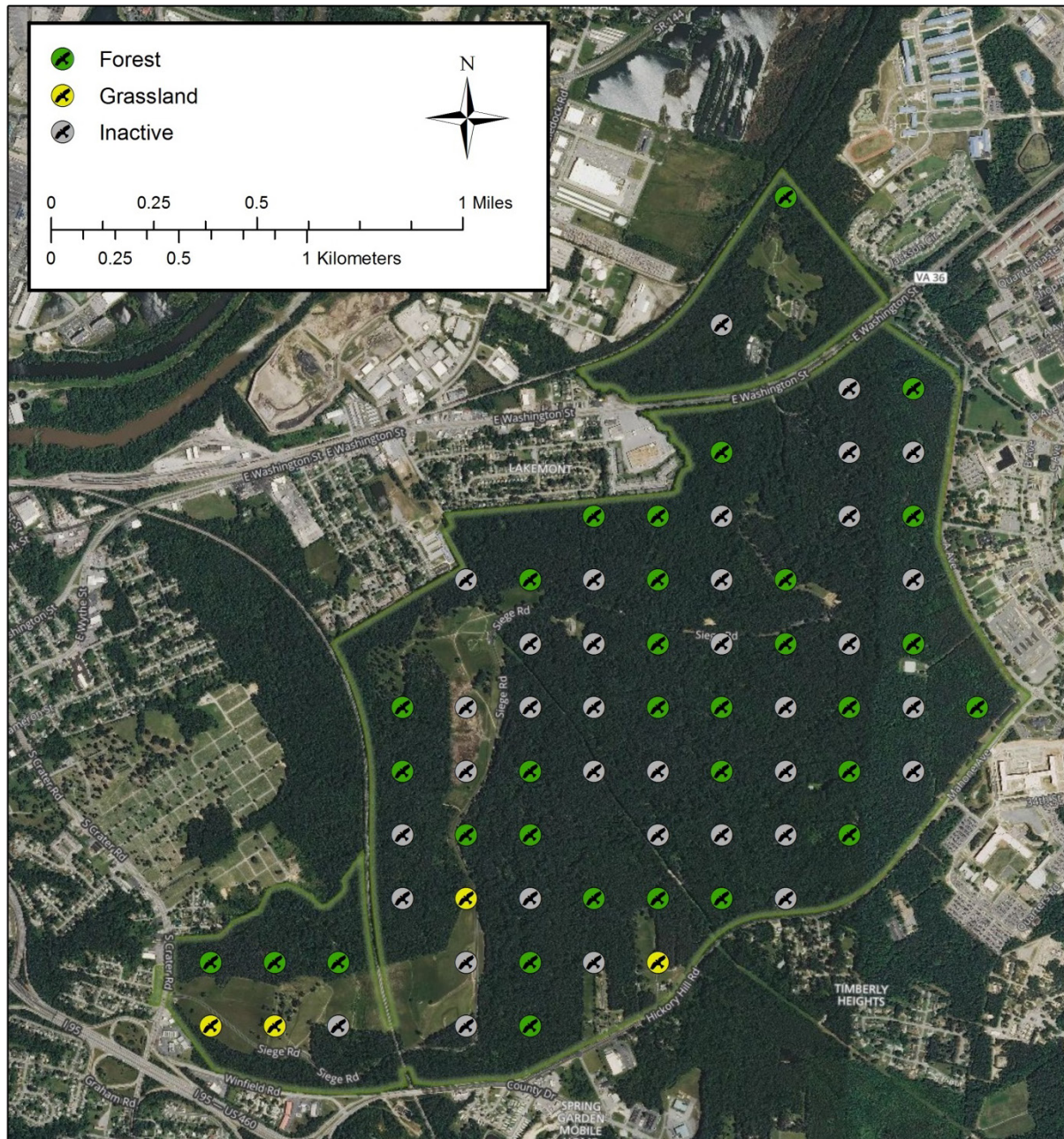


**Figure A3.** Aerial image of the Eastern Front unit of Petersburg National Battlefield (PETE) showing active forest (green) and grassland (yellow) monitoring locations. Previously monitored points that are now inactive are shown in gray.

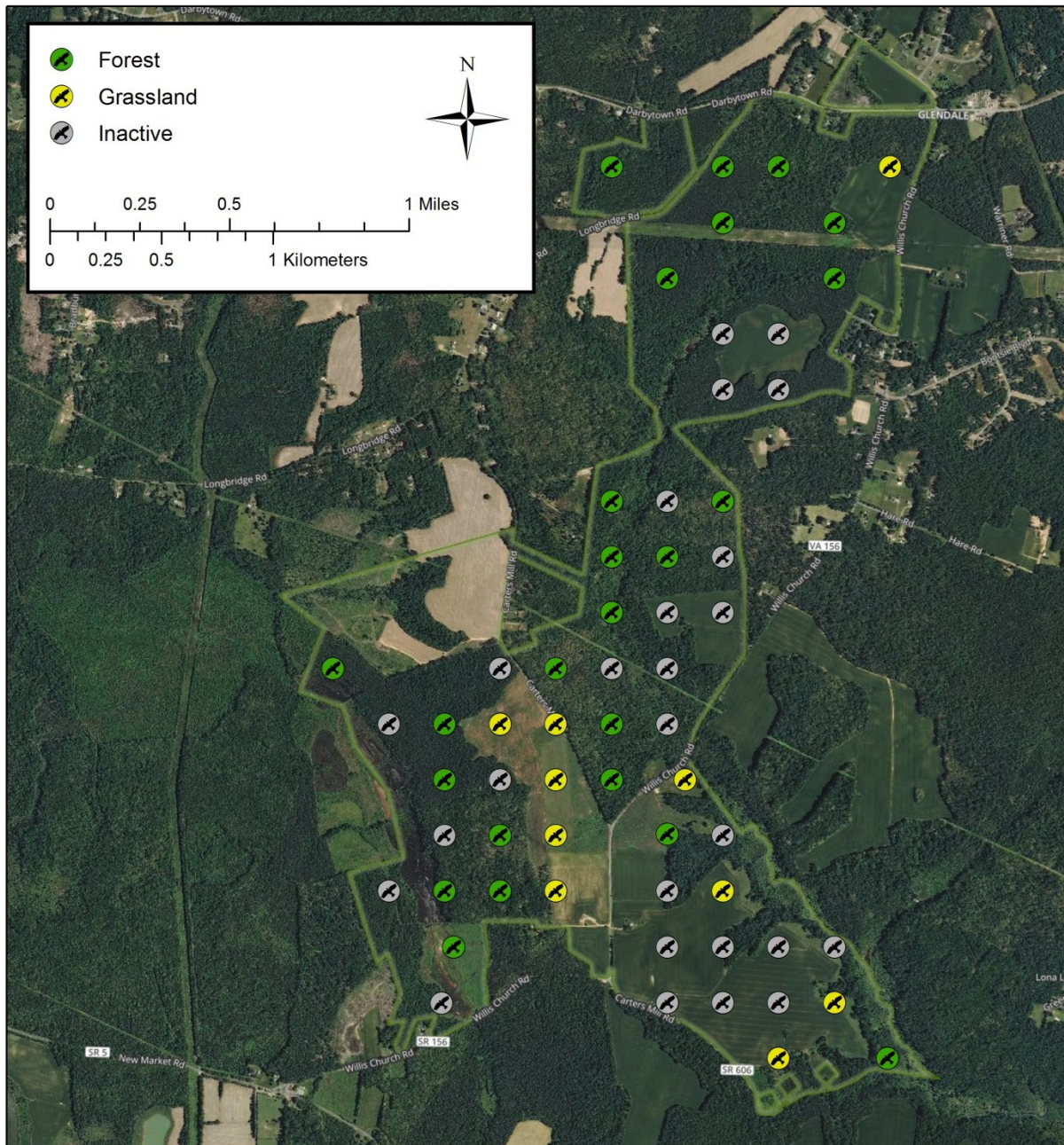


**Figure A4.** Aerial image of the Malvern Hill unit of Richmond National Battlefield Park (RICH) showing active forest (green) and grassland (yellow) monitoring locations. Previously monitored points that are now inactive are shown in gray.

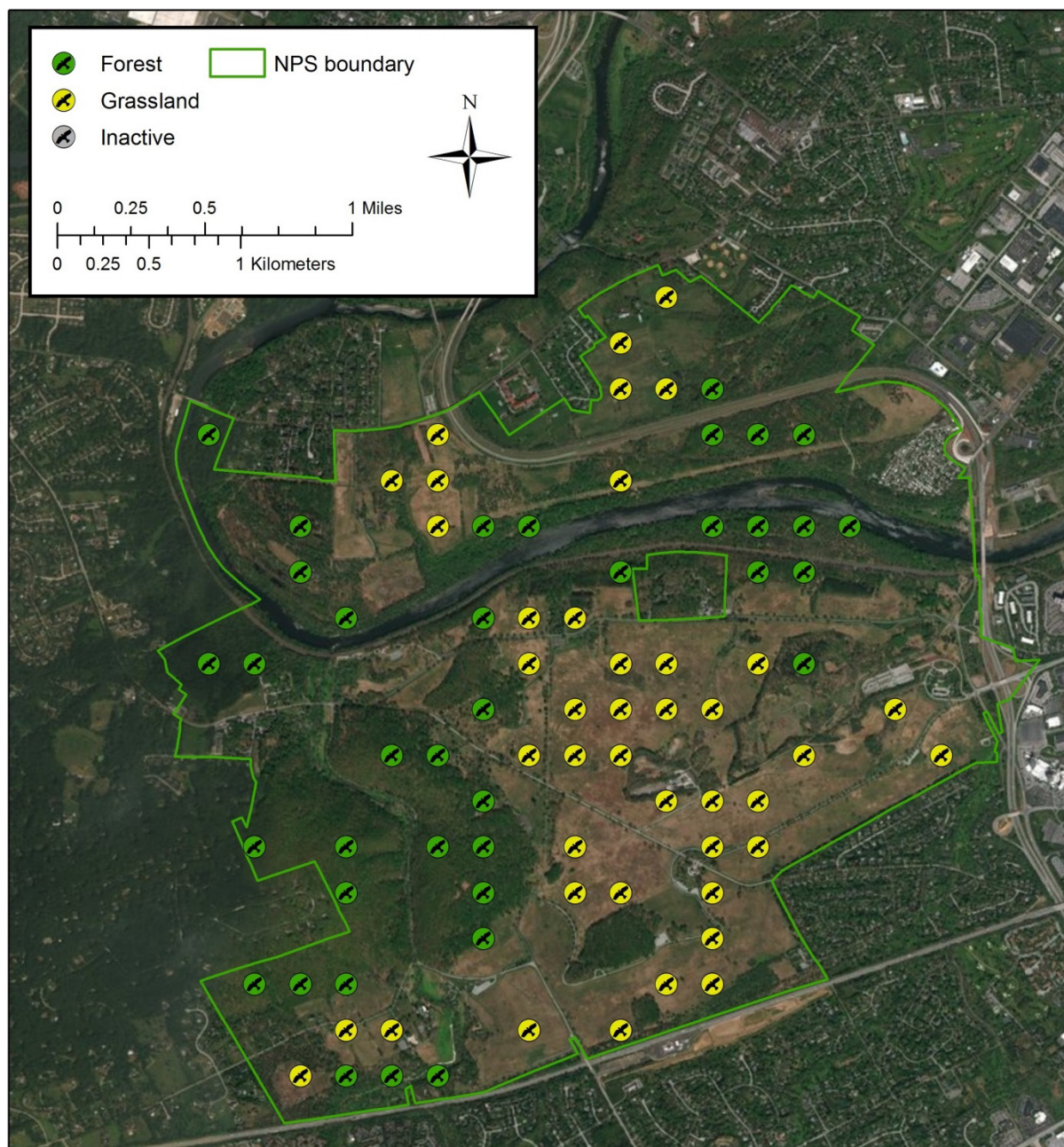


**Figure A5.** Aerial image of Valley Forge National Historical Park (VAFO) showing active forest (green) and grassland (yellow) monitoring locations. Previously monitored points that are now inactive are shown in gray.

## Appendix B. Power Analysis

To evaluate this protocol's ability to detect population changes, the Mid-Atlantic Network (MIDN) initiated a cooperative agreement in 2015 with the University of Delaware to evaluate and review our existing avian monitoring protocol. The results of their evaluation were provided to the MIDN as an internal report (Shriver and Ladin 2016). Subsequent to this report, Drs. Shriver and Ladin performed additional analyses using data from 2009-2017 to estimate our power to detect changes in probability of site occupancy, abundance, and bird community index scores for each of the participating park units within the MIDN. The results of these power analyses are provided below.

Pilot data from 2009 to 2017 field seasons at both forest (N = 230) and grassland (N = 84) survey locations within six MIDN park units were used in the power analysis. The analysis focused on determining the MIDN protocol's ability to detect declines in:

1. Species occupancy and abundance in both forest and grassland habitats
2. Forest bird communities using the bird community index (BCI) developed by O'Connell for the Mid-Atlantic and Coastal Plain (O'Connell et al. 2003).

Assessing power at multiple scales yields a greater understanding of the protocol's ability to detect changes at the species and community levels. The six MIDN park units included in the power analysis are: Appomattox Court House National Historical Park (APCO), Booker T. Washington National Monument (BOWA), Fredericksburg and Spotsylvania National Military Park (FRSP), Richmond National Battlefield Park (RICH), Petersburg National Battlefield (PETE), and Valley Forge National Historical Park (VAFO).

### **Species Occupancy and Abundance**

The first step in determining our protocol's ability to detect declines in species occupancy and abundance is to generate estimates from our pilot data. The 'unmarked' package (Fiske and Chandler 2011) in program R (R Development Core Team 2011) was used to estimate all metrics of interest: species probability of site occupancy, species abundance (i.e., number of individuals per sampling location) and detection probability (likelihood of detection) for 128 species detected at six MIDN park units (Appendix C, Table C1). Prior to estimating these metrics, we removed all detections recorded as "Flyovers", incidentals, or of unknown species, and only included species data where there was a minimum of five detections per park unit per year. Models of occupancy and abundance were limited to points that had a minimum of 2 visits or maximum of 3 visits per year sampled.

### **Occupancy Estimation**

We used the 'unmarked' (Fiske and Chandler 2011) package to estimate the probability of site occupancy for each species. We first converted raw count data to binomial detections (i.e., 0 or 1) and then fit models using the 'occu' function (MacKenzie et al. 2002). This model assumes population closure during the duration of surveys. We included two covariates within the model, 1)

observer as a covariate within the detection process component of the model, and 2) ordinal day as a site-level covariate, to capture within-season temporal effects that can influence occupancy.

### **Abundance Estimation**

The ‘pcount’ function, which fits N-mixture models (binomial mixture models) to repeated count data, was used to estimate abundance, with observer and visit as detection covariates, and park unit and year as site covariates. These models can be used to estimate true unobserved abundance as:  $N_{it} \sim \text{Pois}(\lambda_{it})$ , where  $N$  is the population size at location  $i$ , at time  $t$ , which is a function of the Poisson distribution, in which the mean is equal to the variance, with a mean of  $\lambda$  at location  $i$ , at time  $t$ . This model is then nested within, and influences, the model describing the detection process:  $y_{ijt} \sim \text{Binom}(N_{it}, p_{ijt})$ , where  $y_{ijt}$  is the number of distinct individuals counted at site  $i$ , during visit  $j$ , at time  $t$  which is a function of a binomial random variable with the parameters  $N_{it}$  (population size at location  $i$ , at time  $t$ ) and  $p_{ijt}$  (detection probability,  $p$  at site  $i$ , during visit  $j$ , at time  $t$ ) (Royle 2004, Kéry 2008).

### **Power Analysis**

To determine our power to detect changes in species occupancy and abundance over time, we used the ‘power.t.test’ function of the ‘pwr’ package in program R following the methods outlined in Cohen (1988). The mean and SE of the abundance estimates averaged across years for both forest and grassland habitat types were used in this analysis. Four sampling frameworks of 5-, 10-, 15- and 20-year annual sampling designs were used to illustrate the effect of additional sampling years on power. We set the desired power to 0.75 and significance to alpha level 0.05, and ran separate analyses to estimate power to detect a 10% or 50% decline in species occupancy and abundance for each of the sampling frameworks and for both habitat types (forest and grassland). Results of the power analysis on occupancy and abundance estimates show that we achieved power estimates greater than 0.75 for many species tested, in both forest and grassland habitats (Table B1 and B2). Our power to detect changes in the probability of site occupancy was much higher than for abundance and we should be able to detect changes for more species and over shorter monitoring periods than abundance.

### **Forest Bird Communities**

To evaluate the protocol’s ability to detect declines in forest bird communities, we first generated point-level Bird Community Index (BCI) Scores using the BCI developed by O’Connell for the Mid-Atlantic and Coastal Plain (O’Connell et al. 2003). Data from grassland points, incidentals, flyovers, and unknown species were removed from the analysis, and only species included in the original development of the index were used. However, for this analysis, all sampled points were used regardless of how many times they were visited per year. Species detected at forested points were assigned to the appropriate guilds defined by O’Connell et al. (2003). The relative proportions of each guild category occurring at each point were calculated, each guild category was then assigned a corresponding numerical score (higher scores indicate higher proportions of specialist species). The scores for compositional, functional, and structural guilds were summed for each point, and averaged to estimate mean annual BCI scores for each park (See SOP 10 - Data Analysis and Reporting for more detail).

The power analysis on the BCI scores generated followed the same procedures outlined above for species abundance. Results of the analysis estimate strong power to detect declines in BCI at all participating parks (Table B3). For 5-, 10-, 15- and 20-year monitoring durations, we are able to detect a 10% decline in BCI trend for all parks except APCO with a power >0.90.

**Table B1.** Power estimates to detect a change in species point occupancy (10 or 50 percent declines) under 5-, 10-, 15-, and 20-year annual sampling frameworks for species observed within MIDN park units. Power estimates greater than or equal to 0.75 are indicated by green shading. The top 5 species with the highest power per habitat type are displayed for each park unit. APCO did not have sufficient grassland data to be included. N refers to the number of sampling points included in the analysis.

| Park | Habitat   | AOU Code | N  | 10%<br>5yr | 10%<br>10yr | 10%<br>15yr | 10%<br>20yr | 50%<br>5yr | 50%<br>10yr | 50%<br>15yr | 50%<br>20yr |
|------|-----------|----------|----|------------|-------------|-------------|-------------|------------|-------------|-------------|-------------|
| APCO | Forest    | NOCA     | 25 | 0.413      | 0.879       | 0.981       | 0.998       | 1          | 1           | 1           | 1           |
| APCO | Forest    | REVI     | 25 | 0.241      | 0.602       | 0.815       | 0.922       | 1          | 1           | 1           | 1           |
| APCO | Forest    | YBCU     | 25 | 0.135      | 0.319       | 0.482       | 0.619       | 0.965      | 1           | 1           | 1           |
| APCO | Forest    | INBU     | 25 | 0.0684     | 0.126       | 0.179       | 0.233       | 0.589      | 0.979       | 0.999       | 1           |
| APCO | Forest    | OVEN     | 25 | 0.0585     | 0.099       | 0.136       | 0.173       | 0.451      | 0.912       | 0.99        | 0.999       |
| BOWA | Forest    | GCFL     | 12 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| BOWA | Forest    | PIWO     | 12 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| BOWA | Forest    | TUTI     | 12 | 0.695      | 0.98        | 0.999       | 1           | 1          | 1           | 1           | 1           |
| BOWA | Forest    | NOFL     | 12 | 0.556      | 0.919       | 0.985       | 0.999       | 1          | 1           | 1           | 1           |
| BOWA | Forest    | REVI     | 12 | 0.399      | 0.766       | 0.909       | 0.984       | 1          | 1           | 1           | 1           |
| BOWA | Grassland | AMCR     | 4  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| BOWA | Grassland | EAWP     | 4  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| BOWA | Grassland | INBU     | 4  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| BOWA | Grassland | REVI     | 4  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| BOWA | Grassland | TUTI     | 4  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| FRSP | Forest    | NOFL     | 51 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| FRSP | Forest    | REVI     | 51 | 0.731      | 0.987       | 0.999       | 1           | 1          | 1           | 1           | 1           |
| FRSP | Forest    | EAWP     | 51 | 0.447      | 0.825       | 0.944       | 0.993       | 1          | 1           | 1           | 1           |
| FRSP | Forest    | WOTH     | 51 | 0.416      | 0.789       | 0.923       | 0.988       | 1          | 1           | 1           | 1           |
| FRSP | Forest    | ACFL     | 51 | 0.413      | 0.784       | 0.921       | 0.987       | 1          | 1           | 1           | 1           |
| FRSP | Grassland | BGGN     | 8  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| FRSP | Grassland | RBWO     | 8  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| FRSP | Grassland | SCTA     | 8  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| FRSP | Grassland | EAPH     | 8  | 0.985      | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| FRSP | Grassland | EATO     | 8  | 0.808      | 0.996       | 1           | 1           | 1          | 1           | 1           | 1           |
| PETE | Forest    | ACFL     | 32 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| PETE | Forest    | MODO     | 32 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| PETE | Forest    | REVI     | 32 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| PETE | Forest    | YBCU     | 32 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| PETE | Forest    | CARW     | 32 | 0.122      | 0.279       | 0.352       | 0.485       | 0.941      | 1           | 1           | 1           |

| Park | Habitat   | AOU Code | N  | 10%<br>5yr | 10%<br>10yr | 10%<br>15yr | 10%<br>20yr | 50%<br>5yr | 50%<br>10yr | 50%<br>15yr | 50%<br>20yr |
|------|-----------|----------|----|------------|-------------|-------------|-------------|------------|-------------|-------------|-------------|
| PETE | Grassland | AMRO     | 7  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| PETE | Grassland | BLJA     | 7  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| PETE | Grassland | CARW     | 7  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| PETE | Grassland | NOCA     | 7  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| PETE | Grassland | TUTI     | 7  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| RICH | Forest    | TUVU     | 41 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| RICH | Forest    | YBCU     | 41 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| RICH | Forest    | WEVI     | 41 | 0.998      | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| RICH | Forest    | GCFL     | 41 | 0.995      | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| RICH | Forest    | REVI     | 41 | 0.246      | 0.494       | 0.697       | 0.847       | 1          | 1           | 1           | 1           |
| RICH | Grassland | YBCU     | 18 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| RICH | Grassland | SUTA     | 18 | 0.979      | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| RICH | Grassland | FISP     | 18 | 0.168      | 0.326       | 0.484       | 0.637       | 0.991      | 1           | 1           | 1           |
| RICH | Grassland | INBU     | 18 | 0.168      | 0.325       | 0.482       | 0.635       | 0.991      | 1           | 1           | 1           |
| RICH | Grassland | NOCA     | 18 | 0.134      | 0.248       | 0.37        | 0.499       | 0.964      | 1           | 1           | 1           |
| VAFO | Forest    | BLJA     | 37 | 0.545      | 0.912       | 0.983       | 0.999       | 1          | 1           | 1           | 1           |
| VAFO | Forest    | AMRO     | 37 | 0.536      | 0.906       | 0.981       | 0.999       | 1          | 1           | 1           | 1           |
| VAFO | Forest    | TUTI     | 37 | 0.42       | 0.793       | 0.926       | 0.989       | 1          | 1           | 1           | 1           |
| VAFO | Forest    | RBWO     | 37 | 0.302      | 0.615       | 0.788       | 0.929       | 1          | 1           | 1           | 1           |
| VAFO | Forest    | GCFL     | 37 | 0.198      | 0.403       | 0.555       | 0.741       | 0.998      | 1           | 1           | 1           |
| VAFO | Grassland | EAPH     | 42 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| VAFO | Grassland | RWBL     | 42 | 0.465      | 0.844       | 0.954       | 0.995       | 1          | 1           | 1           | 1           |
| VAFO | Grassland | AMRO     | 42 | 0.433      | 0.809       | 0.936       | 0.991       | 1          | 1           | 1           | 1           |
| VAFO | Grassland | BLVU     | 42 | 0.196      | 0.399       | 0.549       | 0.735       | 0.997      | 1           | 1           | 1           |
| VAFO | Grassland | AMGO     | 42 | 0.189      | 0.382       | 0.528       | 0.712       | 0.996      | 1           | 1           | 1           |

**Table B2.** Power estimates to detect a change in species abundance (10 or 50 percent declines) under 5-, 10-, 15-, and 20-year annual sampling frameworks for species observed within MIDN park units. Power estimates greater than or equal to 0.75 are indicated by green shading. The top 5 species with the highest power per habitat type are displayed for each park unit. APCO did not have sufficient grassland data to be included. N refers to the number of sampling points included in the analysis.

| Park | Habitat   | AOU Code | N  | 10%<br>5yr | 10%<br>10yr | 10%<br>15yr | 10%<br>20yr | 50%<br>5yr | 50%<br>10yr | 50%<br>15yr | 50%<br>20yr |
|------|-----------|----------|----|------------|-------------|-------------|-------------|------------|-------------|-------------|-------------|
| APCO | Forest    | INBU     | 25 | 0.0751     | 0.144       | 0.21        | 0.274       | 0.668      | 0.993       | 1           | 1           |
| APCO | Forest    | NOCA     | 25 | 0.0639     | 0.113       | 0.159       | 0.205       | 0.529      | 0.959       | 0.998       | 1           |
| APCO | Forest    | TUTI     | 25 | 0.0414     | 0.0576      | 0.0713      | 0.0841      | 0.191      | 0.48        | 0.691       | 0.827       |
| APCO | Forest    | RBWO     | 25 | 0.037      | 0.0479      | 0.0568      | 0.0649      | 0.131      | 0.31        | 0.469       | 0.603       |
| APCO | Forest    | CARW     | 25 | 0.036      | 0.0458      | 0.0537      | 0.0608      | 0.119      | 0.273       | 0.414       | 0.539       |
| BOWA | Forest    | LOWA     | 12 | 0.807      | 0.996       | 1           | 1           | 1          | 1           | 1           | 1           |
| BOWA | Forest    | FISP     | 12 | 0.0489     | 0.0663      | 0.0802      | 0.102       | 0.304      | 0.617       | 0.79        | 0.93        |
| BOWA | Forest    | ACFL     | 12 | 0.0471     | 0.0628      | 0.0752      | 0.0947      | 0.275      | 0.564       | 0.739       | 0.898       |
| BOWA | Forest    | NOCA     | 12 | 0.0448     | 0.0585      | 0.0692      | 0.0859      | 0.24       | 0.495       | 0.664       | 0.841       |
| BOWA | Forest    | WBNU     | 12 | 0.0423     | 0.054       | 0.063       | 0.0768      | 0.204      | 0.417       | 0.572       | 0.757       |
| BOWA | Grassland | BGGN     | 4  | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| BOWA | Grassland | EABL     | 4  | 0.262      | 0.539       | 0.712       | 0.879       | 1          | 1           | 1           | 1           |
| BOWA | Grassland | MODO     | 4  | 0.0909     | 0.156       | 0.211       | 0.3         | 0.807      | 0.996       | 1           | 1           |
| BOWA | Grassland | AMCR     | 4  | 0.0451     | 0.0592      | 0.0702      | 0.0872      | 0.246      | 0.506       | 0.676       | 0.851       |
| BOWA | Grassland | TUTI     | 4  | 0.0431     | 0.0554      | 0.0649      | 0.0795      | 0.215      | 0.441       | 0.601       | 0.786       |
| FRSP | Forest    | CHSP     | 51 | 0.302      | 0.614       | 0.787       | 0.929       | 1          | 1           | 1           | 1           |
| FRSP | Forest    | INBU     | 51 | 0.0578     | 0.084       | 0.105       | 0.14        | 0.441      | 0.819       | 0.941       | 0.992       |
| FRSP | Forest    | YBCU     | 51 | 0.0511     | 0.0706      | 0.0863      | 0.111       | 0.338      | 0.677       | 0.843       | 0.958       |
| FRSP | Forest    | ACFL     | 51 | 0.0485     | 0.0655      | 0.079       | 0.1         | 0.297      | 0.605       | 0.779       | 0.923       |
| FRSP | Forest    | CACH     | 51 | 0.0407     | 0.0511      | 0.0589      | 0.071       | 0.181      | 0.365       | 0.506       | 0.689       |
| FRSP | Grassland | SCTA     | 8  | 0.992      | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| FRSP | Grassland | BGGN     | 8  | 0.922      | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| FRSP | Grassland | RBWO     | 8  | 0.839      | 0.998       | 1           | 1           | 1          | 1           | 1           | 1           |
| FRSP | Grassland | EATO     | 8  | 0.681      | 0.976       | 0.998       | 1           | 1          | 1           | 1           | 1           |
| FRSP | Grassland | AMGO     | 8  | 0.0443     | 0.0577      | 0.068       | 0.0841      | 0.233      | 0.48        | 0.647       | 0.827       |
| PETE | Forest    | YBCU     | 32 | 0.998      | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| PETE | Forest    | SUTA     | 32 | 0.394      | 0.856       | 0.938       | 0.989       | 1          | 1           | 1           | 1           |
| PETE | Forest    | PIWA     | 32 | 0.0472     | 0.0705      | 0.0807      | 0.1         | 0.277      | 0.675       | 0.796       | 0.924       |
| PETE | Forest    | REVI     | 32 | 0.039      | 0.0521      | 0.0576      | 0.0678      | 0.158      | 0.384       | 0.483       | 0.645       |
| PETE | Forest    | ACFL     | 32 | 0.0388     | 0.0517      | 0.057       | 0.067       | 0.155      | 0.376       | 0.473       | 0.634       |
| PETE | Grassland | CHSP     | 7  | 0.0346     | 0.0429      | 0.0463      | 0.0524      | 0.104      | 0.225       | 0.283       | 0.392       |
| PETE | Grassland | AMRO     | 7  | 0.0342     | 0.0422      | 0.0453      | 0.0511      | 0.0994     | 0.213       | 0.267       | 0.369       |
| PETE | Grassland | TUTI     | 7  | 0.0298     | 0.0335      | 0.035       | 0.0375      | 0.0566     | 0.0937      | 0.111       | 0.143       |
| PETE | Grassland | CARW     | 7  | 0.0262     | 0.027       | 0.0273      | 0.0279      | 0.0314     | 0.0366      | 0.0386      | 0.0422      |
| PETE | Grassland | BLJA     | 7  | 0.026      | 0.0267      | 0.0269      | 0.0273      | 0.0302     | 0.0343      | 0.0358      | 0.0386      |

| Park | Habitat   | AOU Code | N  | 10%<br>5yr | 10%<br>10yr | 10%<br>15yr | 10%<br>20yr | 50%<br>5yr | 50%<br>10yr | 50%<br>15yr | 50%<br>20yr |
|------|-----------|----------|----|------------|-------------|-------------|-------------|------------|-------------|-------------|-------------|
| RICH | Forest    | YBCU     | 41 | 0.211      | 0.421       | 0.61        | 0.769       | 0.999      | 1           | 1           | 1           |
| RICH | Forest    | PIWO     | 41 | 0.05       | 0.0675      | 0.0854      | 0.106       | 0.321      | 0.634       | 0.836       | 0.942       |
| RICH | Forest    | YTVI     | 41 | 0.0489     | 0.0653      | 0.0821      | 0.101       | 0.303      | 0.603       | 0.808       | 0.926       |
| RICH | Forest    | FISP     | 41 | 0.0376     | 0.045       | 0.0521      | 0.0597      | 0.139      | 0.26        | 0.387       | 0.521       |
| RICH | Forest    | BGGN     | 41 | 0.035      | 0.0407      | 0.0461      | 0.0517      | 0.108      | 0.191       | 0.28        | 0.381       |
| RICH | Grassland | AMCR     | 18 | 0.0704     | 0.108       | 0.148       | 0.196       | 0.613      | 0.945       | 0.995       | 1           |
| RICH | Grassland | COYE     | 18 | 0.0479     | 0.0635      | 0.0793      | 0.097       | 0.288      | 0.575       | 0.782       | 0.909       |
| RICH | Grassland | EAWP     | 18 | 0.0407     | 0.0504      | 0.06        | 0.0703      | 0.181      | 0.354       | 0.523       | 0.68        |
| RICH | Grassland | PIWO     | 18 | 0.0327     | 0.0369      | 0.0407      | 0.0447      | 0.083      | 0.135       | 0.191       | 0.257       |
| RICH | Grassland | FISP     | 18 | 0.0321     | 0.036       | 0.0395      | 0.0432      | 0.0777     | 0.123       | 0.173       | 0.231       |
| VAFO | Forest    | OVEN     | 37 | 0.0615     | 0.0915      | 0.116       | 0.156       | 0.495      | 0.873       | 0.968       | 0.997       |
| VAFO | Forest    | REVI     | 37 | 0.0527     | 0.0738      | 0.0908      | 0.118       | 0.363      | 0.716       | 0.874       | 0.971       |
| VAFO | Forest    | WBNU     | 37 | 0.0508     | 0.0701      | 0.0854      | 0.11        | 0.334      | 0.669       | 0.836       | 0.955       |
| VAFO | Forest    | NOCA     | 37 | 0.0401     | 0.05        | 0.0574      | 0.0688      | 0.173      | 0.346       | 0.48        | 0.66        |
| VAFO | Forest    | DOWO     | 37 | 0.0392     | 0.0483      | 0.0551      | 0.0656      | 0.16       | 0.316       | 0.44        | 0.613       |
| VAFO | Grassland | EAPH     | 42 | 0.999      | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| VAFO | Grassland | RWBL     | 42 | 0.0911     | 0.156       | 0.211       | 0.3         | 0.808      | 0.996       | 1           | 1           |
| VAFO | Grassland | EUST     | 42 | 0.0642     | 0.0971      | 0.124       | 0.169       | 0.533      | 0.904       | 0.98        | 0.999       |
| VAFO | Grassland | CARW     | 42 | 0.0433     | 0.0557      | 0.0654      | 0.0802      | 0.218      | 0.447       | 0.608       | 0.793       |
| VAFO | Grassland | BLVU     | 42 | 0.0425     | 0.0543      | 0.0634      | 0.0774      | 0.207      | 0.422       | 0.579       | 0.764       |

**Table B3.** Power estimates to detect a change in bird community index (BCI) trends (50 or 10 percent declines) under 5-, 10-, 15- and 20-year annual sampling frameworks of forested points in MIDN park units. Power estimates greater than or equal to 0.75 are indicated by green shading.

| Park | Mean   | SE    | 10%<br>5yr | 10%<br>10yr | 10%<br>15yr | 10%<br>20yr | 50%<br>5yr | 50%<br>10yr | 50%<br>15yr | 50%<br>20yr |
|------|--------|-------|------------|-------------|-------------|-------------|------------|-------------|-------------|-------------|
| APCO | 48.167 | 0.937 | 0.737      | 0.998       | 1           | 1           | 1          | 1           | 1           | 1           |
| BOWA | 51.495 | 0.774 | 0.904      | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| FRSP | 53.139 | 0.305 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| PETE | 50.124 | 0.635 | 0.967      | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| RICH | 49.084 | 0.532 | 0.992      | 1           | 1           | 1           | 1          | 1           | 1           | 1           |
| VAFO | 45.699 | 0.347 | 1          | 1           | 1           | 1           | 1          | 1           | 1           | 1           |

## Literature Cited

- Cohen, J. 1988. Statistical power analysis for the behavioral sciences. L. Erlbaum Associates, Hillsdale, N.J.
- Fiske, I. and R. B. Chandler. 2011. Unmarked: An R Package for Fitting Hierarchical Models of Wildlife Occurrence and Abundance.

- Kéry, M. 2008. Estimating Abundance From Bird Counts: Binomial Mixture Models Uncover Complex Covariate Relationships. *The Auk* 125(2):336-345.
- MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. Andrew Royle, and C. A. Langtimm. 2002. Estimating Site Occupancy Rates When Detection Probabilities Are Less Than One. *Ecology* 83(8):2248-2255.
- O'Connell, T. J., R. P. Brooks, M. J. Lanzone, and J. A. Bishop. 2003. A bird community index for the Mid-Atlantic Piedmont and Coastal Plain. Final Report to the USGS Patuxent Wildlife Research Center. Report No. 2003-02, Penn State Cooperative Wetlands Center, University Park, Pennsylvania.
- R Development Core Team. 2011. R: A language and environment for statistical computing. Version: R Foundation for Statistical Computing. Vienna, Austria. <https://www.R-project.org/>
- Royle, J. A. 2004. N-Mixture Models for Estimating Population Size from Spatially Replicated Counts. *Biometrics* 60(1):108-115.
- Shriver, W. G. and Z. S. Ladin. 2016. Review and Testing of Avian Monitoring Protocols for the Mid-Atlantic and National Capital Region I&M Networks of the National Park Service. Internal report to the Mid-Atlantic Network.

## Appendix C. Species List

This appendix contains the list of species detected at the six parks participating in the Mid-Atlantic network breeding bird monitoring program and used in our analysis of occupancy, abundance and Bird Community Index: Appomattox Court House National Historical Park (APCO), Booker T. Washington National Monument (BOWA), Fredericksburg and Spotsylvania National Military Park (FRSP), Richmond National Battlefield Park (RICH), Petersburg National Battlefield (PETE), and Valley Forge National Historical Park (VAFO).

**Table C1.** List of 128 species with corresponding common names, Latin names, and 4-letter American Ornithological Union (AOU) codes detected at forest and grassland monitoring plots within MIDN park units. Asterisks indicate Partners In Flight species of continental concern.

| Common Name                 | Latin Name                       | AOU Code |
|-----------------------------|----------------------------------|----------|
| Acadian Flycatcher          | <i>Empidonax virescens</i>       | ACFL     |
| Alder Flycatcher            | <i>Empidonax alnorum</i>         | ALFL     |
| American Crow               | <i>Corvus brachyrhynchos</i>     | AMCR     |
| American Goldfinch          | <i>Carduelis tristis</i>         | AMGO     |
| American Kestrel            | <i>Falco sparverius</i>          | AMKE     |
| American Redstart           | <i>Setophaga ruticilla</i>       | AMRE     |
| American Robin              | <i>Turdus migratorius</i>        | AMRO     |
| Bald Eagle                  | <i>Haliaeetus leucocephalus</i>  | BAEA     |
| Baltimore Oriole            | <i>Icterus galbula</i>           | BAOR     |
| Bank Swallow                | <i>Riparia riparia</i>           | BANS     |
| Barn Swallow                | <i>Hirundo rustica</i>           | BARS     |
| Barred Owl                  | <i>Strix varia</i>               | BADO     |
| Belted Kingfisher           | <i>Ceryle alcyon</i>             | BEKI     |
| Black Vulture               | <i>Coragyps atratus</i>          | BLVU     |
| Black-and-white Warbler     | <i>Mniotilta varia</i>           | BAWW     |
| Black-billed Cuckoo         | <i>Coccyzus erythrophthalmus</i> | BBCU     |
| Black-capped Chickadee      | <i>Poecile atricapillus</i>      | BCCH     |
| Blackpoll Warbler           | <i>Setophaga striata</i>         | BLPW     |
| Black-throated Blue Warbler | <i>Setophaga caerulescens</i>    | BTBW     |
| Blue Grosbeak               | <i>Guiraca caerulea</i>          | BLGR     |
| Blue Jay                    | <i>Cyanocitta cristata</i>       | BLJA     |
| Blue-gray Gnatcatcher       | <i>Polioptila caerulea</i>       | BGGN     |
| Blue-headed Vireo           | <i>Vireo solitarius</i>          | BHVI     |
| Blue-winged Warbler         | <i>Vermivora cyanoptera</i>      | BWWA     |
| Broad-winged Hawk           | <i>Buteo platypterus</i>         | BWHA     |
| Brown Creeper               | <i>Certhia americana</i>         | BRCR     |
| Brown Thrasher              | <i>Toxostoma rufum</i>           | BRTH     |
| Brown-headed Cowbird        | <i>Molothrus ater</i>            | BHCO     |
| Brown-headed Nuthatch*      | <i>Sitta pusilla</i>             | BHNU     |
| Canada Goose                | <i>Branta canadensis</i>         | CANG     |
| Canada Warbler*             | <i>Cardellina canadensis</i>     | CAWA     |
| Carolina Chickadee          | <i>Poecile carolinensis</i>      | CACH     |
| Carolina Wren               | <i>Thryothorus ludovicianus</i>  | CARW     |
| Cedar Waxwing               | <i>Bombycilla cedrorum</i>       | CEDW     |

| <b>Common Name</b>            | <b>Latin Name</b>                 | <b>AOU Code</b> |
|-------------------------------|-----------------------------------|-----------------|
| Chestnut-sided Warbler        | <i>Setophaga pensylvanica</i>     | CSWA            |
| Chimney Swift                 | <i>Chaetura pelagica</i>          | CHSW            |
| Chipping Sparrow              | <i>Spizella passerina</i>         | CHSP            |
| Common Grackle                | <i>Quiscalus quiscula</i>         | COGR            |
| Common Raven                  | <i>Corvus corax</i>               | CORA            |
| Common Yellowthroat           | <i>Geothlypis trichas</i>         | COYE            |
| Cooper's Hawk                 | <i>Accipiter cooperii</i>         | COHA            |
| Double-crested Cormorant      | <i>Phalacrocorax auritus</i>      | DCCO            |
| Downy Woodpecker              | <i>Picoides pubescens</i>         | DOWO            |
| Eastern Bluebird              | <i>Sialia sialis</i>              | EABL            |
| Eastern Kingbird              | <i>Tyrannus tyrannus</i>          | EAKI            |
| Eastern Meadowlark            | <i>Sturnella magna</i>            | EAME            |
| Eastern Phoebe                | <i>Sayornis phoebe</i>            | EAPH            |
| Eastern Screech-Owl           | <i>Megascops asio</i>             | EASO            |
| Eastern Towhee                | <i>Pipilo erythrophthalmus</i>    | EATO            |
| Eastern Wood-Pewee            | <i>Contopus virens</i>            | EAWP            |
| European Starling             | <i>Sturnus vulgaris</i>           | EUST            |
| Field Sparrow                 | <i>Spizella pusilla</i>           | FISP            |
| Fish Crow                     | <i>Corvus ossifragus</i>          | FICR            |
| Grasshopper Sparrow           | <i>Ammodramus savannarum</i>      | GRSP            |
| Gray Catbird                  | <i>Dumetella carolinensis</i>     | GRCA            |
| Great Blue Heron              | <i>Ardea herodias</i>             | GBHE            |
| Great Crested Flycatcher      | <i>Myiarchus crinitus</i>         | GCFL            |
| Great Horned Owl              | <i>Bubo virginianus</i>           | GHOW            |
| Green Heron                   | <i>Butorides virescens</i>        | GRHE            |
| Hairy Woodpecker              | <i>Picoides villosus</i>          | HAWO            |
| Hooded Warbler                | <i>Setophaga citrina</i>          | HOWA            |
| Horned Lark                   | <i>Eremophila alpestris</i>       | HOLA            |
| House Finch                   | <i>Haemorhous mexicanus</i>       | HOFI            |
| House Sparrow                 | <i>Passer domesticus</i>          | HOSP            |
| House Wren                    | <i>Troglodytes aedon</i>          | HOWR            |
| Indigo Bunting                | <i>Passerina cyanea</i>           | INBU            |
| Kentucky Warbler*             | <i>Oporornis formosus</i>         | KEWA            |
| Killdeer                      | <i>Charadrius vociferus</i>       | KILL            |
| Least Flycatcher              | <i>Empidonax minimus</i>          | LEFL            |
| Louisiana Waterthrush         | <i>Parkesia motacilla</i>         | LOWA            |
| Magnolia Warbler              | <i>Setophaga magnolia</i>         | MAWA            |
| Mallard                       | <i>Anas platyrhynchos</i>         | MALL            |
| Marsh Wren                    | <i>Cistothorus palustris</i>      | MAWR            |
| Mourning Dove                 | <i>Zenaida macroura</i>           | MODO            |
| Nashville Warbler             | <i>Oreothlypis ruficapilla</i>    | NAWA            |
| Northern Bobwhite             | <i>Colinus virginianus</i>        | NOBO            |
| Northern Cardinal             | <i>Cardinalis cardinalis</i>      | NOCA            |
| Northern Flicker              | <i>Colaptes auratus</i>           | NOFL            |
| Northern Mockingbird          | <i>Mimus polyglottos</i>          | NOMO            |
| Northern Parula               | <i>Setophaga americana</i>        | NOPA            |
| Northern Rough-winged Swallow | <i>Stelgidopteryx serripennis</i> | NRWS            |
| Orchard Oriole                | <i>Icterus spurius</i>            | OROR            |

| <b>Common Name</b>        | <b>Latin Name</b>                 | <b>AOU Code</b> |
|---------------------------|-----------------------------------|-----------------|
| Osprey                    | <i>Pandion haliaetus</i>          | OSPR            |
| Ovenbird                  | <i>Seiurus aurocapillus</i>       | OVEN            |
| Palm Warbler              | <i>Setophaga palmarum</i>         | PAWA            |
| Philadelphia Vireo        | <i>Vireo philadelphicus</i>       | PHVI            |
| Pileated Woodpecker       | <i>Dryocopus pileatus</i>         | PIWO            |
| Pine Warbler              | <i>Setophaga pinus</i>            | PIWA            |
| Prairie Warbler*          | <i>Setophaga discolor</i>         | PRAW            |
| Prothonotary Warbler*     | <i>Protonotaria citrea</i>        | PROW            |
| Purple Martin             | <i>Progne subis</i>               | PUMA            |
| Red-bellied Woodpecker    | <i>Melanerpes carolinus</i>       | RBWO            |
| Red-eyed Vireo            | <i>Vireo olivaceus</i>            | REVI            |
| Red-headed Woodpecker*    | <i>Melanerpes erythrocephalus</i> | RHWO            |
| Red-shouldered Hawk       | <i>Buteo lineatus</i>             | RSHA            |
| Red-tailed Hawk           | <i>Buteo jamaicensis</i>          | RTHA            |
| Red-winged Blackbird      | <i>Agelaius phoeniceus</i>        | RWBL            |
| Rock Pigeon               | <i>Columba livia</i>              | ROPI            |
| Rose-breasted Grosbeak    | <i>Pheucticus ludovicianus</i>    | RBGR            |
| Ruby-throated Hummingbird | <i>Archilochus colubris</i>       | RTHU            |
| Savannah Sparrow          | <i>Passerculus sandwichensis</i>  | SAVS            |
| Scarlet Tanager           | <i>Piranga olivacea</i>           | SCTA            |
| Sharp-shinned Hawk        | <i>Accipiter striatus</i>         | SSHA            |
| Song Sparrow              | <i>Melospiza melodia</i>          | SOSP            |
| Summer Tanager            | <i>Piranga rubra</i>              | SUTA            |
| Swainson's Thrush         | <i>Catharus ustulatus</i>         | SWTH            |
| Tennessee Warbler         | <i>Oreothlypis peregrina</i>      | TEWA            |
| Tree Swallow              | <i>Tachycineta bicolor</i>        | TRES            |
| Tufted Titmouse           | <i>Baeolophus bicolor</i>         | TUTI            |
| Turkey Vulture            | <i>Cathartes aura</i>             | TUVU            |
| Veery                     | <i>Catharus fuscescens</i>        | VEER            |
| Vesper Sparrow            | <i>Poocetes gramineus</i>         | VESP            |
| Warbling Vireo            | <i>Vireo gilvus</i>               | WAVI            |
| White-breasted Nuthatch   | <i>Sitta carolinensis</i>         | WBNU            |
| White-eyed Vireo          | <i>Vireo griseus</i>              | WEVI            |
| White-throated Sparrow    | <i>Zonotrichia albicollis</i>     | WTSP            |
| Wild Turkey               | <i>Meleagris gallopavo</i>        | WITU            |
| Willow Flycatcher*        | <i>Empidonax traillii</i>         | WIFL            |
| Wood Duck                 | <i>Aix sponsa</i>                 | WODU            |
| Wood Thrush*              | <i>Hylocichla mustelina</i>       | WOTH            |
| Worm-eating Warbler*      | <i>Helmitheros vermivorus</i>     | WEWA            |
| Yellow Warbler            | <i>Setophaga petechia</i>         | YEWA            |
| Yellow-bellied Flycatcher | <i>Empidonax flaviventris</i>     | YBFL            |
| Yellow-billed Cuckoo      | <i>Coccyzus americanus</i>        | YBCU            |
| Yellow-breasted Chat      | <i>Icteria virens</i>             | YBCH            |
| Yellow-rumped Warbler     | <i>Setophaga coronata</i>         | YRWA            |
| Yellow-throated Vireo     | <i>Vireo flavifrons</i>           | YTVI            |
| Yellow-throated Warbler   | <i>Setophaga dominica</i>         | YTWA            |



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 962/148595, September 2018

National Park Service  
U.S. Department of the Interior



---

**Natural Resource Stewardship and Science**

1201 Oakridge Drive, Suite 150  
Fort Collins, CO 80525